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BULLETINS

of the

AGRICULTURAL EXPERIMENT STATION

WEST VIRGINIA UNIVERSITY

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June, 1916 Bulletin 152

West Virginia University
Agricultural Experiment Station
MORGANTOWN, W. VA.

# WHITE BURLEY TOBACCO

## EXPERIMENTS AND CULTURAL DIRECTIONS

BY

I. S. Cook and C. H. Scherffius

IN CO-OPERATION WITH BUREAU OF PLANT INDUSTRY,
U. S. DEPARTMENT OF AGRICULTURE

The Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of Agricultural Experiment Station, Morgantown, W. Va.

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*In co-operation with U. S. Department of Agriculture.
†In co-operation with the University of Chicago.

# White Burley Tobacco

By I. S. COOK and C. H. SCHERFFIUS.

In the spring of 1913 an appropriation was made by the West Virginia Legislature to the Experiment Station, for the purpose of conducting experiments with tobacco. Along with this appropriation, the Bureau of Plant Industry of the United States Department of Agriculture furnished additional funds for co-operative tobacco work and the junior writer of this bulletin was appointed field agent in charge of tobacco investigations. This tobacco work was started late in the spring of 1913 and consisted of three fertilizer experiments, located at Milton, Hurricane and West Hamlin, and a variety test located at Milton. Previous to this time, very little work had ever been done with tobacco by the West Virginia Experiment Station.

While the tobacco-producing area of West Virginia is limited, yet the total value of the crop amounts to more than a half-million dollars. The following figures give the amount of tobacco that passed through the Huntington tobacco warehouse for the yearly periods each beginning in July and continuing till July the following year:

| Year | Production in lbs. | Total Value | Ave. Value per cwt. |
|---|---|---|---|
| 1912 to 1913 | 5,163,676 | $613,862.81 | $11.88 |
| 1913 to 1914 | 6,023,505 | 712,978.91 | 11.87 |
| 1914 to 1915 | 4,499,055 | 366,243.11 | 8.10 |
| 1915 to 1916 | 4,195,690 | 564,982.27 | 13.46 |

These figures represent the amount of tobacco that was raised in this state and marketed through the Huntington tobacco warehouse. The tobacco growers in counties of Ohio and Kentucky adjoining the Huntington district also market tobacco in Huntington, amounting to about the same number of pounds as that produced in this state, although the value of it is less since the quality is not so good as the tobacco raised in West Virginia. Their average price per hundred pounds is less than that received by West Virginia growers for each year indicated above.

The type of tobacco grown is the White Burley which is chiefly used in the manufacture of chewing tobacco, although some of the better grades are largely used for pipe and cigarette purposes and to a limited extent for the manufacture of cigars.

## SELECTION OF SOIL AND ROTATIONS.

All tobacco growers prefer a virgin soil, and one on which white oak, walnut, maple, and hickory grow naturally seems to produce tobacco of fine quality. While a virgin soil cannot usually be had, a soil that is fertile, containing an abundance of organic matter, making it loose and mellow, will produce fine tobacco. Good bluegrass sod land produces the best quality of Burley tobacco and a very good yield, but in the tobacco sections of this state very little bluegrass sod land is ever plowed. A clover sod will furnish the next best conditions for a good yield, but the tobacco does not have the quality of that secured from a bluegrass sod. Although a few farmers are rotating their crops and growing clover by liming their land, the majority of farmers have not limed and consequently their meadows are composed almost entirely of timothy and orchard grass. When a tobacco crop follows this kind of sod not nearly such good yields are secured as after clover or some other leguminous crop, although the quality of leaf is better. Therefore, the grower must determine whether he wants a high yield or the best quality of tobacco.

The methods of cropping the land in the tobacco sections of this state are so haphazard that farmers do not know from one year to the next on what fields they are going to grow tobacco. It is more necessary to have a definite and fixed rotation in tobacco growing than in many other kinds of farming. The following rotation may be practiced with good results in the tobacco growing districts:

| Field | 1st Year | 2nd Year | 3rd Year | 4th Year | 5th Year |
|---|---|---|---|---|---|
| No. 1 | Corn & Tobacco (C.C.) | Soybeans | Wheat | Clover and Timothy | Timothy |
| No. 2 | Soybeans | Wheat | Clover and Timothy | Timothy | Corn & Tobacco (C.C.) |
| No. 3 | Wheat | Clover and Timothy | Timothy | Corn & Tobacco (C.C.) | Soybeans |
| No. 4 | Clover and Timothy | Timothy | Corn & Tobacco (C.C.) | Soybeans | Wheat |
| No. 5 | Timothy | Corn & Tobacco (C.C.) | Soybeans | Wheat | Clover and Timothy |

(C. C.)—Cover crop of rye.

This five-year rotation will require five small areas of ground. The corn and tobacco crops are intended to occupy the same area of land as is occupied by any one of the other crops. Farmers who grow tobacco will also grow corn, and tobacco following corn or corn following tobacco is not a good practice. Since a smaller acreage of tobacco is usually grown than that of hay or wheat it would be a better practice to divide the field for the corn and tobacco crops, devoting one-half of the area to each crop. The advantages of this rotation over others are several but that of producing the highest quality of tobacco and at the same time keeping up the fertility of the soil by growing a cover crop and two leguminous crops in the rotation is of sufficient importance to recommend such a rotation. By growing soybeans for hay following the corn and tobacco crops there is sufficient time for getting a good growth of rye before turning under to sow soybeans which are usually sown during the latter half of May or first of June.

If not enough land is available for dividing it into five tracts, it will be necessary to practice a three or four year rotation such as the following:

| Field | 1st Year | 2nd Year | 3rd Year |
|---|---|---|---|
| No. 1 | Corn and Tobacco | Wheat | Clover and Timothy |
| No. 2 | Wheat | Clover and Timothy | Corn and Tobacco |
| No. 3 | Clover and Timothy | Corn and Tobacco | Wheat |

This rotation may be made into a four-year rotation by not plowing the clover and timothy sod after the first hay crop but leaving it for a timothy crop the second year, then plowing for tobacco and corn, one-half of the field being devoted to corn and the other half to tobacco as in the five-year rotation. While this rotation does not provide a green manuring crop nor a second nitrogen-gathering crop as in the first rotation, it is far better than no definite rotation. The fertility of the soil can be maintained or increased by making liberal use of high grade fertilizers and by utilizing all of the farm manure produced on the place.

Tobacco growers must avoid growing corn after tobacco or tobacco after corn as these two cultivated crops are entirely too hard on the land when following each other, and it will be necessary either to leave out one of these from the rotation or to divide the area of the field between them. Many farmers believe that tobacco is harder on land than any other crop, but the bad practice of following no definite rotation has been

responsible for this idea. Corn or timothy may deplete the soil of its fertility as rapidly as tobacco if no green manuring or leguminous crops are in the rotation in which they are grown. Tobacco, being a crop capable of bringing in large cash returns, so tempts farmers to grow it often on the same land that the fertility question is overlooked.

The best tobacco soils are the Huntington silt loam, Holston silty clay loam, Holston silt loam, and Tyler silt loam. The Huntington silt loam produces the best-paying crops of tobacco and extends over a larger area than any of the other soil types mentioned. A typical section where this soil occurs is along Beech Fork of the Twelvepole Creek. The Holston silty clay loam lies along the Guyandotte Valley Railroad and is good corn and tobacco soil. While it does not extend over as large an area as the Holston silt loam, the yield and quality of the tobacco grown on it are usually better.

A Type of Tobacco Curing Shed too Commonly Used.

## VARIETIES.

The variety grown almost exclusively in the tobacco sections is that known as Lockwood's Burley. There is no question but that this variety has given excellent results in the past. Owing perhaps to the lack of attention given to the selection of seed from the better plants, this variety is not giving as high a yield of the best quality of tobacco as it formerly did. In the spring of 1913 a variety test was conducted at Milton which included eight varieties, seven of which were secured from the Kentucky State Experiment Station and the other being Lockwood's Burley. The plots were 1-30 of an acre in size and Lockwood's Burley was grown on every third plot. The following table gives the results of the test:

| Variety | Lbs. per Plot | Yield per Acre Lbs. |
|---|---|---|
| Hope's Standup Burley | 78.5 | 2355 |
| Holley's White Burley | 70.7 | 2121 |
| Renaker's Standup Burley | 77.3 | 2319 |
| Hisle's White Burley | 71.5 | 2145 |
| Station Standup Burley | 55.8 | 1674 |
| Lockwood's Burley | 46.5 | 1395 |
| Selection of White Twist Bud | 71.0 | 2130 |
| Hullett's White Burley | 73.5 | 2205 |

The seed of these varieties was not sown until April 23, which was very late for growing good plants. This was due to the fact that plans for carrying on the tobacco tests were not completed until quite late in the spring. The plants were transplanted July 5 which was too late to get the tobacco matured properly. The result was that considerable damage was done to the tobacco in the barn by an early freeze in the fall. Two or three of the varieties tested gave promise of proving superior to Lockwood's Burley in quality as well as in yield.

## CULTURAL DIRECTIONS.

There is no definite time for sowing tobacco seed any further than to say that it may be sown either in winter or in spring, and it is undecided which is the better time. In fact, winter sowing will suit one farmer while spring sowing will suit another. One advantage in sowing in the winter is to get the work done before spring is at hand because in spring farmers are usually very busy and are more likely to neglect putting their seed beds in proper condition. In winter the

ground is wet and more burning is required, so the gain is about equal to the loss. Good plants may be had, though, either from winter or spring sowing, but spring sowing should not be later than the last of March.

The plant bed should be made in some good fertile place having good drainage and being well exposed to the sun. It is best to find some place in the woods where the soil is loose and friable. This soil usually has enough decayed vegetable matter and is also handy to plenty of wood, shrubbery, brush, etc. which may be used for burning.

The main object in burning a tobacco bed is to kill insects, and weed and grass seeds that may be in the soil. A good method is to lay small poles or skids over the area to be burned, at intervals of from three to four feet, and then to pile brush and dry wood on one end of the skids. After setting fire to the brush the burning material is pulled forward a few feet on the skids whenever the soil becomes sufficiently heated and sterilized to a depth of two or three inches. It will be necessary to pile more brush on from time to time in order to get the soil evenly burned. After removing all debris, the soil is thoroughly spaded to a depth of four or five inches. Before seeding, a fertilizer consisting of 5 pounds of dried blood and 2 pounds of acid phosphate for each 100 square feet of bed is to be worked into the soil. The rate of sowing should be a level teaspoonful of seed to 100 square feet of bed. If sown too thick, the plants will be tall and spindling, while if sown too thin they will be too short for setting and getting desirable results. After seeding, the bed should be covered with canvas to protect it from cold winds. The canvas should be allowed to remain till a week or ten days before time for setting. It can then be removed in order that the plants may harden before being taken up for transplanting; otherwise, the hot sun might kill the young tender plants.

## PREPARATION OF SOIL.

The ground intended for tobacco should be plowed in the fall, if there is no danger of washing, especially if it is sod land or land on which weeds have been allowed to grow. If it is newly cleared land or land free from dry vegetation, it may be plowed early in the spring and the results obtained will be satisfactory.

Sufficient time after plowing is needed to get the ground in a fine tilth, so as to give the best possible conditions for starting the plants to growing rapidly. The principal reason why sod land should be plowed in the fall is to give the sod

time to rot, and also to kill insects that might prove injurious to the young tobacco plants. Early in the spring the land should be pulverized thoroughly by cultivating with a disk harrow and dragging with a peg tooth harrow. Sometimes it is necessary that the ground be re-broken before harrowing and dragging. The next step is laying off the ground. This, however, will be discussed under the subject of transplanting.

A Good Type of Air Curing Tobacco Barn.

## FERTILIZERS.

The fertilizer requirements of different soils for growing good tobacco vary considerably, due to the way the soil has been handled in previous years. The amount of plant food constituents required for a tobacco crop of 1000 pounds per acre including stalks is as follows:

| | |
|---|---|
| Nitrogen | 46 lbs. |
| Phosphoric acid | 8 " |
| Potash | 35 " |

These figures show that the tobacco plant uses a relatively small amount of phosphoric acid, yet it has proved profit-

able to apply a fertilizer relatively high in this plant food constituent. This is due to the fact that phosphorus in West Virginia soils is in combination with elements which form insoluble compounds and unless some available phosphorus is applied the maximum production will not be attained. What has been said in regard to the available supply of phosphorus applies also to potassium. While West Virginia soils contain large quantities of potash compounds, crops requiring relatively large amounts of this plant food constituent cannot secure their requirements. This deficiency of available potash is probably due to the lack of decaying vegetable matter and lime in the soil. The system of farming followed in the tobacco districts did not provide for a leguminous or green manuring crop and consequently the soils have been robbed of their nitrogen to such an extent that it will not be profitable to farm them until organic matter and nitrogen are restored.

The fertilizer work that has been carried on for the last three years has not been entirely satisfactory, owing to the fact that it was not possible to lease sufficient land from farmers for a period of years so that a definite rotation could be carried out. Since a different area of land at each place had to be rented every year, all plots were either duplicated or repeated four times at each location in order to make the work as accurate as possible. The following table gives the results of two years' test at Hurricane. No work was done at Hurricane during 1915.

| Fertilizing Materials | Acid Phosphate Per Acre | Nitrate of Soda Per Acre | Sulphate of Potash Per Acre | Yields in Lbs. Per Acre |
|---|---|---|---|---|
| No fertilizer | | | | 745 |
| Nitrate of Soda, Acid Phos- and Sulphate of Potash | 200 | 125 | 80 | 967 |
| Acid Phosphate and Sulphate of Potash | 300 | | 100 | 897 |
| Local fertilizer, .82-8-4, 400 lbs. per acre | | | | 807 |
| Nitrate of Soda | | 300 | | 870 |
| Sulphate of Potash | | | 300 | 800 |
| Acid Phosphate | 300 | | | 765 |
| Barnyard manure, 10 tons per acre | | | | 1045 |

The soil on which this fertilizer test was conducted is known as the Tyler silt loam which is rather a heavy soil, often greatly in need of drainage. Due to the way in which this soil has been handled in the past, it appears to be greatly

in need of nitrogen but with the addition of both acid phosphate and sulphate of potash a considerable increase in the yield of tobacco was secured. Manure has given the best results of all fertilizing materials applied. Not many tobacco farmers keep any more livestock on their farms than is necessary to farm their land and furnish milk for the home. The most common fertilizer used is one analyzing one percent ammonia, eight percent phosphoric acid and four percent potash, costing $25.00 per ton two years ago. It has given only a slight increase in yield, due perhaps to the low percentage of nitrogen which it carries.

The results of the fertilizer test at Milton are shown in the following table. Ground limestone was applied to one-half of all the plots at the rate of 2000 pounds per acre.

| Fertilizing Materials | Acid Phosphate Per Acre | Nitrate of Soda Per Acre | Sulphate of Potash Per Acre | Manure Tons Per Acre | Yields in Lbs. Per Acre |
|---|---|---|---|---|---|
| No fertilizer | | | | | 1287 |
| Acid Phosphate, Nitrate of Soda and Sulphate of Potash | 200 | 100 | 100 | | 1580 |
| Manure | | | | 8 | 1440 |
| Acid Phosphate, Nitrate of Soda and Sulphate of Potash | 260 | 60 | 80 | | 1570 |
| Acid Phosphate and Sulphate of Potash | 300 | | 100 | | 1370 |
| Nitrate of Soda and Sulphate of Potash | | 225 | 175 | | 1405 |

Lime alone did not increase the yield of tobacco but the limed halves of the plots receiving fertilizers produced 126 pounds per acre more than the halves receiving no lime.

In addition to the regular fertilizer work at Milton in 1914, one acre of land was rented for the purpose of determining the net profit from growing tobacco where a high grade mixed fertilizer was applied at the rate of 700 pounds per acre and the necessary cultivations given to the tobacco. The fertilizing materials applied were 300 pounds of acid phosphate, 200 pounds of nitrate of soda and 200 pounds of sulphate of potash.

Fertilizer tests have been carried on in the Guyandotte Valley in both Cabell and Lincoln counties, on the Holston silty clay loam soil which is recognized by all tobacco growers as being perhaps the best soil type for raising Burley tobacco.

The first two years' test, indicating the fertilizing materials applied and the results obtained, is shown in the following table:

| Fertilizing Materials | Acid Phosphate Per Acre | Nitrate of Soda Per Acre | Sulphate of Potash Per Acre | Yields in Lbs. Per Acre |
|---|---|---|---|---|
| No fertilizer | | | | 1073 |
| Acid Phosphate, Nitrate of Soda and Sulphate of Potash | 200 | 100 | 100 | 1325 |
| Local fertilizer, .82-8-4, 400 lbs. per acre | | | | 1116 |
| Acid Phosphate, Nitrate of Soda and Sulphate of Potash | 260 | 60 | 80 | 1265 |
| Acid Phosphate and Sulphate of Potash | 300 | | 100 | 1250 |
| Nitrate of Soda and Acid Phosphate | 175 | 225 | | 1290 |
| Nitrate of Soda and Sulphate of Potash | | 225 | 175 | 1280 |
| Nitrate of Soda | | 300 | | 1260 |
| Acid Phosphate | 300 | | | 1190 |

An Inexpensive Curing Barn with Good Ventilation.

Nitrogen seems to be the controlling element since the yield of tobacco on this type of soil was either high or low, depending upon the amount of nitrogen that was applied. A fertilizer with a relatively high percent of phosphorus, as compared with potassium, will no doubt pay better on this soil than the reverse as indicated by the yield of tobacco, and especially would this conclusion be reached if grain were grown in rotation with tobacco on this soil type.

In 1915 the plan of the tobacco fertilizer test on this soil type was changed and the different fertilizing materials were applied in sufficient amounts so that no one material would be lacking for a maximum yield. All plots were repeated four times with every fifth one a check plot.

| Fertilizing Materials | Acid Phosphate Per Acre | Nitrate of Soda Per Acre | Sulphate of Potash Per Acre | Yields in Lbs. Per Acre |
|---|---|---|---|---|
| No fertilizer | | | | 1360 |
| Acid Phosphate | 500 | | | 1410 |
| Acid Phosphate and Nitrate of Soda | 500 | 250 | | 1700 |
| Acid Phosphate and Sulphate of Potash | 500 | | 200 | 1475 |
| Acid Phosphate, Nitrate of Soda and Sulphate of Potash | 500 | 250 | 200 | 1710 |
| Acid Phosphate, Dried Blood and Sulphate of Potash | 500 | 250* | 200 | 1650 |
| Acid Phosphate, Nitrate of Soda, Sulphate of Potash and Lime† | 500 | 250 | 200 | 1700 |
| Nitrate of Soda and Sulphate of Potash | | 250 | 200 | 1590 |

*Dried blood.

†Lime, 2000 lbs. per acre.

In 1914 one acre of land was set aside at Milton for the purpose of determining the approximate cost of growing tobacco when a high grade fertilizer was applied at the rate of 700 pounds per acre. Ground limestone was applied at the rate of one ton per acre and a fertilizer mixture of 200 pounds sodium nitrate, 300 pounds acid phosphate and 200 pounds potassium sulphate was used on the acre of land. It would perhaps have been better if tankage or dried blood had been used as the carrier of nitrogen in order to produce a leaf of finer texture.

| | |
|---|---|
| Yield of tobacco secured on one acre | 1640 pounds |
| Weight after reaching market | 1610 " |
| Cash received from Huntington Tobacco Warehouse Co. | $98.65 |
| Cost of growing and marketing tobacco | 66.40 |
| Net returns for one acre | $32.25 |

The following itemized expense account shows the cost of different operations in growing the tobacco:

| | |
|---|---|
| Preparing plant bed—1 day | $ 1.50 |
| Breaking—½ day @ $3.00 | 1.50 |
| Disking—½ day | 1.50 |
| Spreading lime and dragging | 1.50 |
| Applying fertilizer—¼ day | .75 |
| Cost of fertilizer | 12.00 |
| Cost of lime | 4.00 |
| Transplanting—2 men, 1 day | 3.00 |
| Cultivating four times—1 horse, 1 day | 2.50 |
| Hoeing two times—2 days | 3.00 |
| Topping, worming and suckering | 4.50 |
| Cutting and housing—2 men, 2 days | 7.50 |
| Stripping and grading—3 men, 4½ days | 20.25 |
| Hauling to market—2 men, ½ day | 3.00 |
| Total cost | $66.50 |

No doubt some of these items cost more than they would cost the average farmer, but the net returns show that where lime and a liberal application of a high grade fertilizer were used a good profit was secured, and the land was kept in a fairly rich condition. In fertilizing Burley tobacco some attention should be given to the carrier of nitrogen. In other states, fertilizer tests show that inorganic carriers of nitrogen produce tobacco having a coarser texture than do organic carriers. So far no coarseness of leaf has been noticed with nitrate of soda on soils of West Virginia, but further tests may give different results. The tobacco on each plot of the 1915 test was valued by a tobacco buyer but very little variation existed between the different plots. The tobacco grown with complete fertilizer with nitrate of soda as the carrier of nitrogen averaged one cent per pound higher than that grown with dried blood as the carrier of nitrogen, due to the fact that there was a larger percent of bright leaf produced on the nitrate of soda plot.

## TRANSPLANTING.

When the young plants have grown about five inches high, they are ready for transplanting. They should be transplanted in rows about 3½ feet apart, and spaced about 18 inches in the row. These distances, however, are determined largely by the soil on which the tobacco is to be grown. If the soil is very fertile the plants may be set closer, while on a very thin soil, they may be given more room. For fertile soils, close setting tends to produce tobacco with a thin silky leaf which will cure brighter than it would otherwise. In setting small plants, care should be taken not to bruise them or to destroy the plants. In setting, a good method is as follows: mark the rows off first and then drag a chain, roll a wheelbarrow or use some similar device across the rows, making the tracks the distance apart that you wish to have the plants. Then set one row on the checks or crosses and the next between the crosses and so on. This method gives all rows the same number of plants and also gives them an even distribution. It is not a good idea to "guess" at the distances, especially when more than one man is setting the plants, as this is sure to cause irregularity.

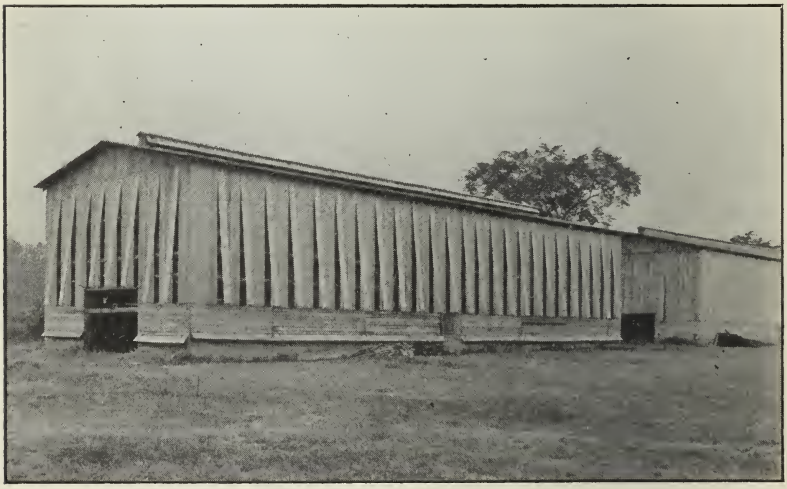
In two or three days after the plants have been set, the field should be gone over and any plants that have died may be replaced by fresh ones. This operation should be repeated the following week, since it is essential to have, as nearly as possible, a perfect stand.

## CULTIVATION OF PLANTS.

About the time the plants have started to grow, the field should be given a shallow but thorough cultivation. This operation should be repeated at least once a week until the plants have reached such growth that cultivating will injure them, or until the plants are about ready to be topped. The cultivation of tobacco should always be thorough but shallow. Keep the top of the soil worked into a good loose mulch, and go over the field occasionally with a hoe and cut out any weeds or bunches of grass that may have been missed while cultivating.

## TOPPING.

When about half of the plants have begun to develop seed heads, or bloom out, the field is ready to be gone over and topped. This process consists simply in breaking the tops out so that the leaves will become larger and more fully developed. The number of leaves to be left on the plant is to be determined by the man doing the topping. He must be able to judge each and every plant and he should top the plants so as to make them, as nearly as possible, mature at the same time. Topping is a very important part of tobacco culture, because topping too low will cause the leaves to be coarse and thick, and topping too high will cause them to fall short of their growth. Uneven topping will cause uneven ripening in the field, thus making harvesting tedious and giving trouble all the way through.



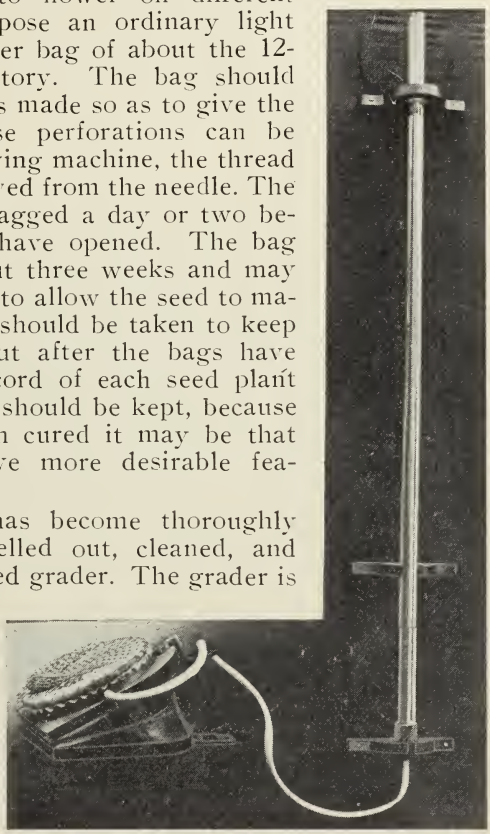
An Ideal Type of Barn for Air Curing, with Ventilators Along the Peak of the Roof, Adapted to the Use of Heat in Curing.

## SELECTION OF SEED PLANTS.

In selecting seed plants, close attention should be given to all the points that go to make up the ideal plant, according to the standard which the grower should have clearly in mind. The largest plants in the richest part of the field are

not necessarily best for seed purposes. In order to have pure strains of seed, it is necessary to cover the seed head during the blossoming period so as to prevent mixing or crossing with inferior plants or suckers due to the passing of insects from flower to flower on different plants. For this purpose an ordinary light weight but strong paper bag of about the 12-pound size is satisfactory. The bag should have small perforations made so as to give the seed head air. These perforations can be easily made with a sewing machine, the thread having first been removed from the needle. The seed head should be bagged a day or two before the first flowers have opened. The bag should be left on about three weeks and may then be removed so as to allow the seed to mature in the sun. Care should be taken to keep all blooms plucked out after the bags have been removed. A record of each seed plant and of each seed head should be kept, because after tobacco has been cured it may be that some plants will have more desirable features than others.

After the seed has become thoroughly dry, it should be shelled out, cleaned, and graded in a tobacco seed grader. The grader is a very simple device consisting of a long glass tube, connected to a foot bellows by means of a small rubber hose. In the bottom of the glass, is fixed a wire gauze to keep the seed from running through. The grading is done by putting the seed into the glass tube and by air pressure, blowing the light and immature seed over the top of the glass, leaving only the strong heavy seed in the tube. This machine will clean about one ounce of seed at a time, and it will take about five minutes to clean each ounce. There is no danger of mixing seed as only a smooth glass tube contains the seed, and after cleaning one lot, the seeds are all poured out and the tube well cleaned before putting in any more.



Device for Cleaning Tobacco Seed.

## HARVESTING.

Only two methods of harvesting tobacco are employed in this state. In one method the plant is split to within about six inches of the ground and is then cut and placed astride a stick and left in the field until wilted. In some cases, the stick is stuck into the ground, while in others it is left flat on the ground, but in either case the tobacco is allowed to wilt before being hauled to the barn. In the second method the

Showing Method of Spudding Tobacco.

tobacco is handled in much the same way except instead of splitting the stalk, it is first cut and then forced on the stick by the use of a sharp spear called a "spud." The "spud" is about eight inches long and is made to slip down over the end of the stick, the latter, of course, first being sharpened. This method is spoken of as "spudding." It is difficult to say just which method is the better, though it is an evident fact that a plant that has been split will cure more quickly than one that has been spudded, and will no doubt give better results for late cutting. One method is about as rapid as the other.

The sticks upon which the tobacco is placed are usually four or four and one-half feet long, and will hold from five to

eight plants of tobacco, the number being determined by the size of the plants. After the tobacco has wilted enough so that it can be handled without breaking, it is hauled to the barn and hung on the tier poles, the sticks being placed about 12 inches apart. Care should be taken in hanging the tobacco in the barn. The plants should be well spaced on the sticks, and the leaves all left to hang as free as possible. It is a good idea to shake the stalks well. This shaking will separate any leaves that may be stuck together, thus preventing them from probable house-burning.

## CURING.

There are too many changes that take place in curing tobacco to try to describe the process in full detail, but the subject is so important that it should be given some consideration. The prime requisite for curing tobacco properly is to have a good barn and to have it well ventilated. Have the doors and windows closed at night and on foggy days. During rainy weather when the air in the barn becomes saturated with moisture it may be necessary to build fires under the tobacco in order to prevent damage by house-burn. The common open curing shed as used in this state should be displaced by good closed barns with windows and ventilators in them. With poorly constructed curing sheds a grower has no control over unfavorable weather conditions and the tobacco may be considerably damaged in the process of curing, thus reducing its value greatly. When weather conditions are favorable, tobacco can be cured very well in open sheds, but such conditions cannot be depended upon. Tobacco in an open shed will damage after having been cured. A well ventilated barn could be built for an amount of money equal to that lost by the open curing shed in two or three crops. Such a barn need not be expensive, as has been shown by some good growers.

## STRIPPING AND GRADING.

When tobacco is thoroughly cured it is ready for stripping but it is better, before stripping, to allow it to go through one or two freezes. This, however, may prevent early stripping which in some cases may be necessary. Consequently, it cannot always be allowed to freeze before stripping.

Stripping and grading tobacco is a very particular part of tobacco production and should be given the closest possible attention. Tobacco is graded into the following

grades: "Flyings," "Trash," "Lugs," "Bright Leaf," "Red Leaf," "Tips," and "Green" or "Damaged."

The grades should be evenly classed while tying; all long leaves should be tied separately from the short ones. This will make, from each grade, two or three sub-grades. It is only necessary, however, to keep the grades separate. Farmers often do not understand why their tobacco does not bring the same price as their neighbors' when their tobacco is of equal quality, but this state of affairs is easily answered after examining the tobacco of the different growers as placed on the market. It may be seen that one grower has graded and classed his tobacco more carefully, making his better grades show off to better advantage and thus obtaining a higher price for them.

## SUMMARY.

1. The value of the tobacco sold in this state amounts to more than a half million dollars.

2. Tobacco growers should follow a definite rotation in which a winter cover crop and a legume are provided.

3. Introduced varieties of White Burley grown from selected seed give promise of proving superior to the standard variety that is grown in all the tobacco districts of the state.

4. Nitrogen influences the yields of tobacco on the soils of this state more than does either potash or phosphoric acid.

5. A combination of all three plant food constituents produced the highest average yield of tobacco and an application of about 700 pounds of a high grade fertilizer containing not less than 4% of nitrogen was profitable.

6. To secure good seed, the blooms should be grown under paper bags on carefully selected plants and when harvested the seed should be graded with a tobacco seed grader.

7. The common open tobacco curing sheds used in this state are a cause of poorly cured tobacco. They should be replaced by closed, well ventilated tobacco barns which need not be expensive.

8. Stripping and grading tobacco require very careful attention, and well graded tobacco will command much higher prices than the same tobacco poorly graded.

August, 1915 Bulletin 153

West Virginia University
Agricultural Experiment Station
MORGANTOWN, W. VA.
DEPARTMENT OF FARM MANAGEMENT

# AN AGRICULTURAL SURVEY
OF
# BROOKE COUNTY

BY
O. M. JOHNSON and A. J. DADISMAN

The Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of Agricultural Experiment Station, Morgantown, W. Va.

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*In co-operation with U. S. Department of Agriculture.
†In co-operation with the University of Chicago.

1—A well built barn. 2—Planting soybeans. 3—An alfalfa field. 4—Preparing land for alfalfa. 5—There are many good brick houses in Brooke County built fifty or more years ago.

# An Agricultural Survey of Brooke County

By O. M. JOHNSON and A. J. DADISMAN.

## INTRODUCTION.

The agriculture of any region is generally recognized as one of the important industries. The continuous success of this industry will depend in large measure upon the class of people that is attracted to it in the future. The attractions of any occupation are both social and economic but the fundamental importance of good economic conditions is not likely to be over estimated. If farming is to attract the young men of the country it must yield profits sufficient to justify their staying on the farms. Various industrial developments in the state have brought opportunities for ambitious young men, however agriculture offers a comfortable living to more people than do most other lines of endeavor.

The 1910 census figures show that 62.2 percent of the land area of West Virginia is in farms About one-third of the state is in timber land; this area is largely mountainous. A large part of the state is made up of broad rolling hills more suited to grazing than to cultivation but there are many fertile valleys among the hills which make up the best agricultural lands of the state. The mineral wealth has had a great influence on agriculture in much of the state. The industrial development during the last fifty years has given many farm owners an income sufficient to reduce the incentive to work their farms. The great diversity of conditions in the state brings about many farm management problems.

Farm management treats of the business of farming with a view to making the farm return the greatest continuous profits. The purpose of the Brooke County farm management survey was to determine the most profitable types of farming, the status of agricultural production, and the methods of farm management now practiced in this region. If a farm is to be a business success it must pay farm expenses, interest on the investment and wages for all farm labor. The successful farms are found to have one or more enterprises which are

conducted in such a way as to yield a good profit. These profitable enterprises, however, are not the same on all farms of the region but the combination of enterprises must be organized so as to meet the individual needs of each farm.

## HOW THE SURVEY WAS MADE.

In the summer of 1914 the Office of Farm Management, of the Bureau of Plant Industry, United States Department of Agriculture, co-operating with the West Virginia Agricultural Experiment Station and the Pan Handle Agricultural Club made a farm management survey of Brooke County, West Virginia. Agricultural conditions were practically normal in the county that year, except that the fruit failed. This county was selected for the survey because it is typical of the northern part of the state and the interest of the Pan Handle Agricultural Club,* an organization of the farmers in the county, was such as to make the work immediately useful.

A circular letter explaining the survey was sent to each farmer for the purpose of acquainting him with the work. Each farmer was visited at his farm and asked questions from a blank provided for the purpose. The survey was made by the writers and Professor A. C. Workman. Farmers were universally courteous, and cheerfully answered all questions in so far as they could.

**Calculating Results.** All field blanks were checked and copied by the men who took the records. They were then checked by the man in charge of the field party and again checked in the office at Washington. When there was any doubt as to the accuracy of the record the farmer was visited the second time or additional information was obtained by mail. The results of this survey are compiled from the records of 201 farms.

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*Much valuable assistance was rendered by Professor A. C. Workman, a representative of the Pan Handle Agricultural Club, in collecting the data. Acknowledgement is also due the farmers of Brooke County who made this study possible by their interest and cooperation.

## EXPLANATION OF TERMS USED IN THIS REPORT.

In order that the terms used in this discussion may be clear, the ones which might not be understood are explained below. Familiarity with these terms will aid in interpreting the results given.

**The Operator** is the person who plans and manages the operations of the farm. He may be either the owner or tenant.

**The Landlord** is the person who owns the farm and leases it to another.

**The Tenant** is the person who operates a farm which is leased from another person.

**An Inventory** is a list of all farm property on hand with values assigned.

**Capital** is the amount of money invested in land, buildings, machinery, stock, supplies and cash for general farm expenses. An average of the values at the beginning and the end of the year is the capital for the year.

**Farm Receipts** include all returns from sales of crops, stock and stock products, from labor and other miscellaneous sources, and from the increase in inventory.

**Farm Expenses** include all sums paid out for the support of the farm business such as stock, feed, repairs, improvements, machinery, taxes, etc., and any decrease in inventory.

**Farm Income** is the difference between the farm receipts and expenses. It is the amount that the farmer and his capital earn.

**Labor Income** is the amount which the farmer receives for his labor and managing ability. It is found by deducting interest at 5 percent on the capital, from the farm income. In addition to the labor income the farm furnishes a house to live in and farm products such as meat, butter, eggs, vegetables and flour for home use.

**Crop Index** is a number used for comparing the yields of crops grown on a given farm with the average yield of the region. The average yield is represented by 100.

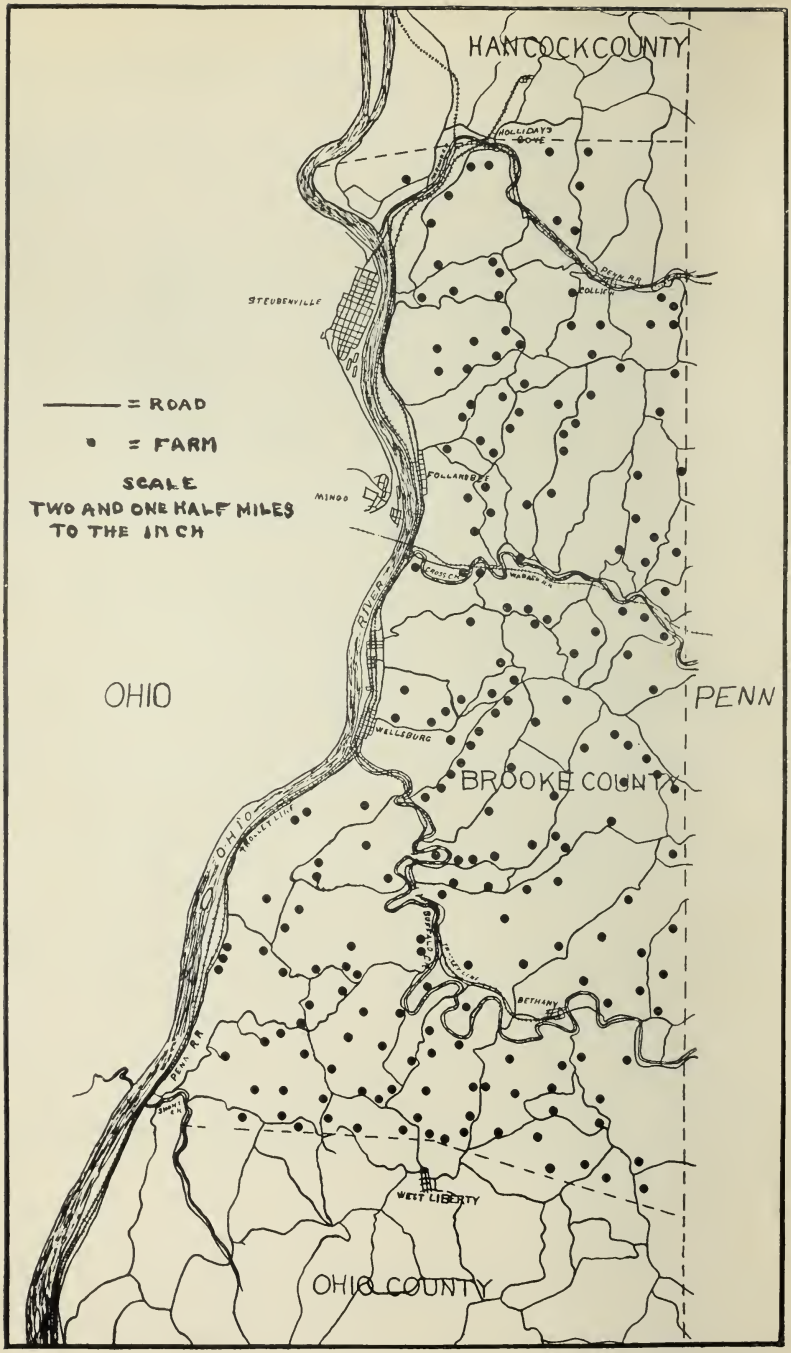
**A Labor Unit** for a horse or man represents approximately an average day's work.

**An Animal Unit** represents one horse, cow or the equivalent in other stock, based upon the amount of feed eaten.

**A Farm** includes all the land operated by one man. It may be owned, rented, or partly owned and the remainder rented. Usually the land is in one tract but it may be in two or more.

**Family Income** is the sum of the farm income and the value of the family labor.

**Man Equivalent** represents the number of men that would be required to do the work of the farm, if they work the entire year. The work is not distributed over the entire year, much more of it is done in some months than in others. The farmer's time is considered as twelve months.




Map showing location of Brooke County, distribution of farms surveyed, roads, streams and towns.

## DESCRIPTION OF BROOKE COUNTY.

Brooke County, West Virginia, is in what is known as the Northern Pan Handle of the state. The county has an area of 87 square miles and a population of about 11,100. The land is generally rolling to hilly and intersected by many ravines. There are narrow bottoms at intervals along the Ohio River but much of the river is bordered by steep hills. There is but very little bottom land along the smaller streams. This county is part of an ancient upland plain which has been dissected by ages of erosion. In some parts of the county there are small areas of coal and petroleum. Practically all of the original forests have been removed and the land which is not too steep is being cultivated or used for pasture.

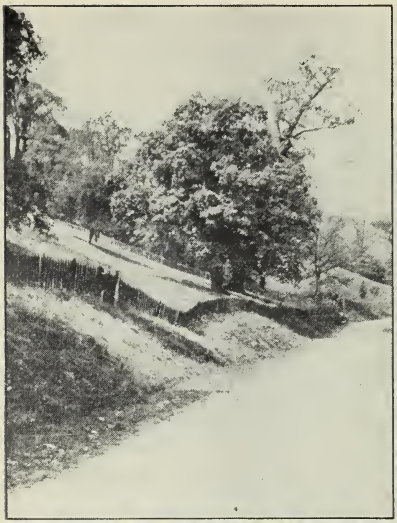
The climate is well suited to carrying on general farming. The average date of the last killing frost in spring is about April 11, and the first in the fall about October 26th, thus the growing season is approximately 200 days. The average annual rainfall is almost 40 inches, more than a proportional part of which falls in June and July.

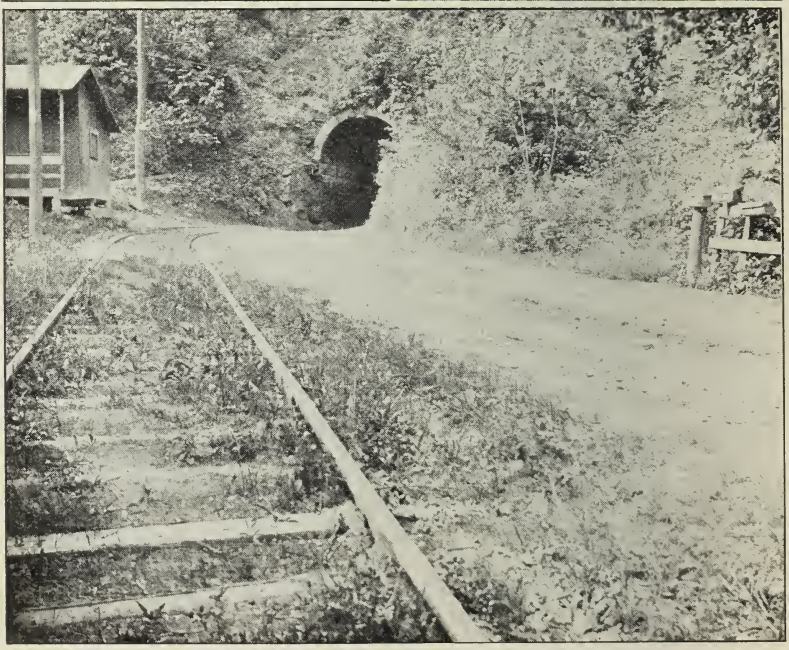
The soil of 95 percent of the county is a clay loam. Along the steams there is some rough stony land which can hardly be called a soil type.

The chief crops are corn, oats, wheat, rye, hay and truck crops. On some farms fruit growing is of considerable importance. Sheep and dairy cattle are the chief livestock grown.

The principal towns are Wellsburg and Follansbee, the population of the two numbering about 7,000. Wheeling and Steubenville, nearby cities having a combined population of nearly 70,000, afford good markets.

The shipping facilities afforded by the Ohio River, Pennsylvania and Wabash Railroads, and trolley lines, are very good. The county borders the Ohio River along which extends the Pennsylvania Railroad and a trolley line. The Pennsylvania Railroad also crosses the northern part of the county and the Wabash crosses it near the middle. Another trolley line extends almost across the southern part of the county. All these roads carry both passengers and freight. The county roads have been but little improved, they are very muddy in winter but very good in summer. There is a macadamized road across the middle of the county and some other roads are being built.



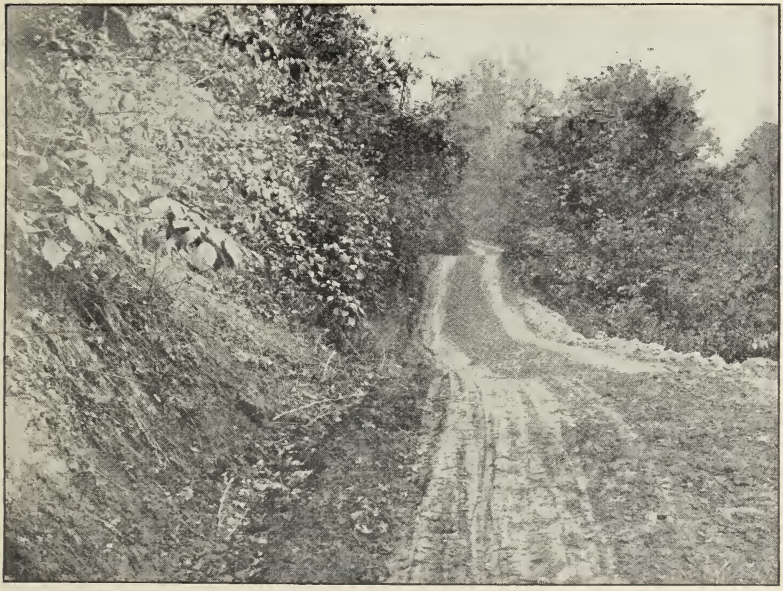


1—A well graded road. 2—Using an auto truck for hauling supplies to the country. 3—A tunnel built fifty years ago to shorten a country road; now used by a trolley line also.

## STATISTICS FOR BROOKE COUNTY, 1850-1910.

Since no changes in the boundaries of the county have been made since 1848 when Hancock County was formed, the census reports show the progress of the county beginning with 1850.

**Population, Improved Land and Value of Farms.** The increase in population has been much more noticeable during



A steep hill road.

the past twenty years, during which time towns have grown rapidly. While the population of many of these is classed as rural, the interests are almost entirely in other industries. The growth and change in population will influence the agriculture in the future.

It seems probable that some of the changes in the area of improved land must be due to some confusion as to the classification used by the census enumerators at different times. There is no tendency to increase the amount of land under cultivation.

The high point in the value of farm property, reached in 1870, was due to the inflated condition of currency, but the rise has been very marked in the past decade. It is possible

that the new land cleared during the period 1860 to 1870 may have increased the value per acre.

**Population, Improved Land and Value of Farms.**

| Census year | Population | Acres of improved land | Value of land and buildings |
|---|---|---|---|
| 1850 | 4,954 | 33,811 | $1,279,368 |
| 1860 | 5,443 | 41,099 | 2,447,903 |
| 1870 | 5,367 | 54,856 | 3,548,075 |
| 1880 | 6,013 | 35,642 | 2,941,124 |
| 1890 | 6,660 | 44,582 | 2,575,840 |
| 1900 | 7,219 | 44,792 | 2,272,030 |
| 1910 | 11,098 | 36,977 | 3,050,920 |

**Crop Production.** The annual production of no staple crop was as large in 1910 as had been reported for some former census. Hay is the only crop showing a marked increase over 1850.

**Crop Production—1850-1910.**

| Census year | Corn (Bushels) | Oats (Bushels) | Wheat (Bushels) | Hay (Tons) |
|---|---|---|---|---|
| 1850 | 150,571 | 51,729 | 65,516 | 4,755 |
| 1860 | 142,129 | 64,940 | 23,490 | 5,445 |
| 1870 | 185,576 | 81,135 | 45,559 | 7,570 |
| 1880 | 162,809 | 61,390 | 62,623 | 6,180 |
| 1890 | 137,354 | 86,750 | 49,057 | 8,606 |
| 1900 | 164,560 | 74,340 | 40,600 | 8,611 |
| 1910 | 153,560 | 60,255 | 20,758 | 8,139 |

**Livestock Production.** Two noteworthy changes have come about in this branch of farming. There are about one-fourth as many sheep in the county as there were in 1850 and about twice as many dairy cows. About the same number of horses is found on farms now as during the earlier periods. Hogs have decreased in number since 1890. The total value of all livestock has risen steadily since 1880.

**Livestock—1850-1910.**

| Census year | Number of dairy cows | Number of other cattle | Number of horses | Number of sheep | Number of swine | Value of all livestock |
|---|---|---|---|---|---|---|
| 1850 | 1,101 | 1,584 | 1,278 | 59,426 | 5,984 | $223,067 |
| 1860 | 1,319 | 1,513 | 1,399 | 40,620 | 3,309 | 282,439 |
| 1870 | 1,060 | 1,439 | 1,230 | 46,581 | 2,920 | 265,944 |
| 1880 | 1,484 | 1,845 | 1,318 | 45,734 | 4,295 | 240,227 |
| 1890 | 1,637 | 2,277 | 1,616 | 25,679 | 5,044 | 270,840 |
| 1900 | 1,794 | 2,320 | 1,498 | 20,043 | 3,500 | 285,352 |
| 1910 | 2,041 | 1,468 | 1,326 | 15,152 | 2,097 | 309,841 |

While changes in agriculture are evident from these reports, no marked increases have been made since the first census of the county in 1850.

## INFLUENCE OF SIZE OF BUSINESS UPON PROFITS.

In tabulating and studying the records it has been noticeable that the farms making large labor incomes as well as those making large minus labor incomes are the farms with a large business. The size of the business is limited by the acreage except in the case of the specialized farm. The small general farm furnishes a living and a home for the family; but the opportunities for efficiency in utilizing labor, for growing a sufficient number of acres of crops, and keeping enough productive stock, are limited. The size of business may be measured in the following ways: acres in the farm, crop acres, animal units, labor units and gross income.

The average size of the 201 farms in Brooke County is 150 acres. The farms range from 12 acres, the smallest, to 488 acres, the largest. Two conditions make it impossible to get a good measure of the size of business from the number of acres in the farm. First, there is a considerable amount of unused land on some large farms; second, there are a number of small specialized farms doing a large business on a small area of ground. For this reason, tables showing the influence of acreage on labor income are of no value.

**Crop Acres Related to Labor Income.** Crop acres include the acreage in meadow, orchard, truck and all grain crops. The average number of crop acres per farm is 56.3.

TABLE I.—*Crop Acres Related to Labor Income, 192 Farms. (Truck Farms Excluded.)*

| Crop Acres | Number of farms | Labor income |
|---|---|---|
| 20 or less | 23 | $ 23 |
| 21 to 40 | 41 | 8 |
| 41 to 60 | 51 | 20 |
| 61 to 80 | 41 | 51 |
| 81 to 100 | 18 | 277 |
| Over 100 | 18 | 616 |
| **Average, 56.3** | | **$104** |

Table I shows the labor income of farms with 20 or less crop acres to be $23. While there are more crop acres in the next two groups of farms the labor income is smaller. These fall in the class of general farms with a small crop acreage. After the number of crop acres reaches 80 the labor income rises with additional crop acres. The group of farms with more than 100 crop acres has the largest labor income.

**Man Labor Related to Labor Income.** A labor unit rep-

resents approximately an average day's work. Some farmers have their work so organized that they can do an average day's work in less than a day.

TABLE II.—*Productive Man Labor Related to Labor Income, 201 Farms.*

| Productive man labor units | Number of farms | Average number of man labor units | Labor income |
|---|---|---|---|
| 100 or less | 19 | 74 | $129 |
| 101 to 200 | 45 | 151 | −27 |
| 201 to 300 | 60 | 249 | 63 |
| 301 to 400 | 38 | 344 | 116 |
| 401 to 500 | 22 | 434 | 317 |
| Over 500 | 17 | 647 | 526 |

It will be seen from the table that the group of farms with an average of 74 man labor units made $129 labor income. This group includes some of the farms which are producing for special markets. On the small farms there is not enough work to keep the men busy and they work off the farms thus adding directly to their labor income with practically no expense. The investment is also small and the interest charge is correspondingly low. A distinct increase in the labor income is noted in the group of farms with over 400 man labor units.

**Gross Receipts Related to Labor Income.** The gross receipts include all farm receipts. The increased inventory of farm property other than land is counted a farm receipt, but increases in land value are not considered.

TABLE III.—*Gross Income Related to Labor Income, 201 Farms.*

| Gross income | Number of farms | Average gross income | Average labor income |
|---|---|---|---|
| Under $400 | 22 | $ 256 | −$197 |
| 401 to 800 | 41 | 575 | −39 |
| 801 to 1200 | 45 | 993 | 1 |
| 1201 to 1600 | 35 | 1,384 | 114 |
| 1601 to 2000 | 19 | 1,791 | 166 |
| 2001 to 2400 | 11 | 2,223 | 163 |
| 2401 to 2800 | 9 | 2,633 | 430 |
| 2801 to 3200 | 5 | 2,924 | 534 |
| Over 3200 | 14 | 4,807 | 1,281 |

The group of farms with less than $400 gross receipts has an average labor income of minus $197. In general there is a gradual rise in labor income as the gross receipts rise. In the group of farms with more than $3,200 gross receipts the labor income is $1,281; the chance of making this labor income is about 1 in 14.

The preceding tables show that there is a direct relation between the size of farm business and labor income. The size

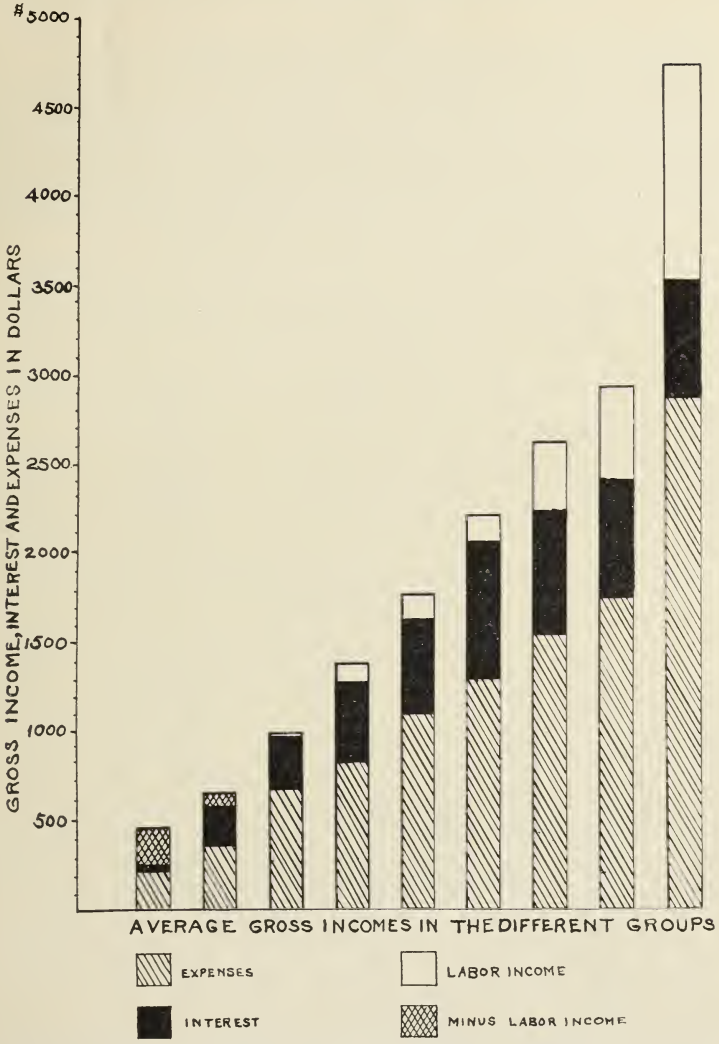



Diagram showing the distribution of gross incomes of different sizes among expenses, interest, and labor income.

of farm business is difficult to measure. Each of the three preceding tables measures a particular phase of it to some extent and they all show in a general way that labor income rises with an increase in the size of farm business. The seeming exception in the case of the groups having the smallest total number of acres, crop acres, man labor units and animal units is due to the fact that these farms with a small business get prices for their products which enable them to make fair labor incomes.

## AMOUNT AND DISTRIBUTION OF CAPITAL.

**Amount of Capital Invested.** The type of farming is the chief factor in determining the amount and distribution of capital on farms with the same income. A profitable truck farm can be operated with much less capital than a general farm or a dairy farm having equivalent receipts.

TABLE IV.—*Family Income of Farms Classified According to Capital Invested.*

158 FARMS OPERATED BY OWNERS.

| Capital | Number of farms | Average capital | Family income |
|---|---|---|---|
| Average of all farms | | $10,764 | $ 737 |
| $ 5,000 or less | 33 | $ 3,558 | $ 432 |
| 5,001 to 10,000 | 57 | 7,445 | 535 |
| 10,001 to 15,000 | 37 | 12,239 | 878 |
| Over 15,000 | 31 | 22,777 | 1,262 |

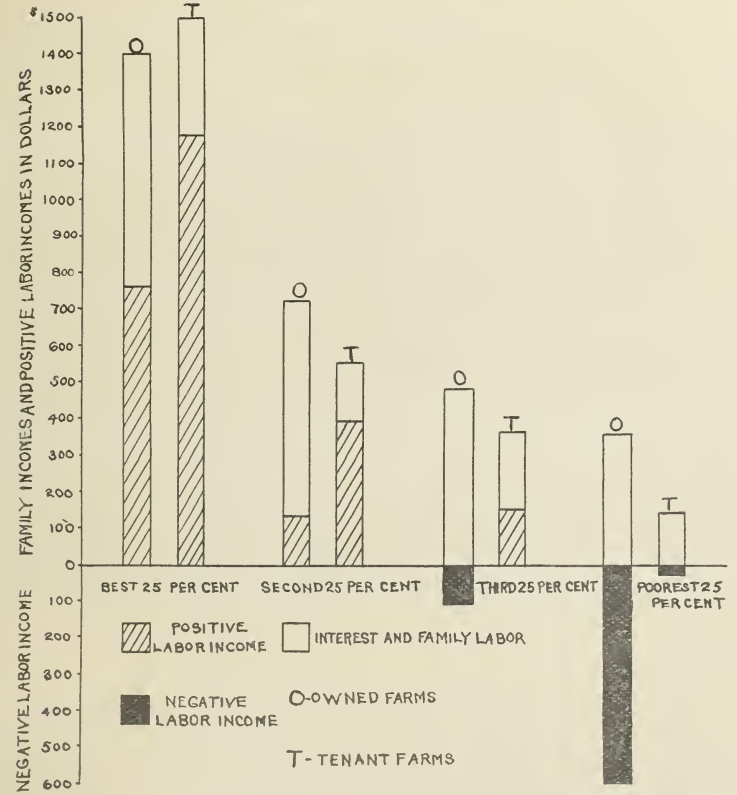
TABLE V.—*Family Income of Farms Classified According to Capital Invested.*

43 FARMS OPERATED BY TENANTS.

| Capital | Number of farms | Average capital | Family income |
|---|---|---|---|
| Average of all farms | | $1,399 | $ 642 |
| $1,000 or less | 17 | $ 704 | $ 272 |
| 1,001 to 2,000 | 16 | 1,402 | 554 |
| Over 2,000 | 10 | 2,577 | 1,410 |

Family income includes the value of family labor, interest on capital and labor income, and is the amount of money available for the family's living and the payment of interest on indebtedness. In so far as the family is concerned, net income is the important thing and in this discussion, the family is the unit rather than the farm operator. The distinction is clearly drawn in the case of farms operated by owners where the labor income is only $45 while the family income is $737. On the average tenant farm the labor income is $421 while the family income is $642 or about $100 less than on farms operated by owners. Interest on investment is deducted in figuring labor incomes; this interest on farms operated by owners is very much greater than on farms operated by tenants since the investment is much greater. The tenant has but little to live on except labor income and is, therefore, compelled to make a labor income; but the owner can live reasonably well without a high labor income, if he has a large investment, for

which reason he frequently does not strive to make a large labor income. In the group of farms with largest capital, which averages nearly $23,000, the labor income is minus $88, yet the family income is $1262. These men have an investment in farm property, the interest on which is making them a good living, and furnishes them a home even though they are really getting nothing from their labor.




Comparison of family incomes and labor incomes in four groups of farms operated by owners and tenants.

An additional reason for the larger labor income of the tenant is found in the fact that the rent paid amounts to only three percent on the investment in land. If the tenant were charged five percent on the value of the land as is the owner, the labor income of the tenant would be $239 instead of $421, while that of the owner is only $45. This difference is large enough to show a distinct advantage in favor of the tenant farmer.

The tenant's capital is much less than that of the owners operating their own farms. The farms operated by tenants show a rise in family income as the amount of capital increases. The tenants with over $2,000 capital are operating farms efficiently and making more than hired men's wages.

A recent investigation shows that the average contribution to the family living made by the farm in ten localities in the eastern part of the United States was $421.17 per family of 4.6 persons. This includes the value of food, fuel and the rent of the house and must be added to the labor income when farmers' incomes are compared to those of workers in town.*

**Distribution of Capital.** More than four-fifths of the total capital is invested in real estate. One who has but little capital can best begin farming as a tenant, since in this case the landlord furnishes the larger part of the capital.

TABLE VI.—*Distribution of Capital on Farms Operated by Owners and Tenants.*

| | 158 farms operated by owners | | 43 farms operated by tenants | | 201 farms | |
|---|---|---|---|---|---|---|
| | Average capital | Percentage of total capital | Average capital | Percentage of total capital | Average capital | Percentage of total capital |
| Total capital | $10,764 | 100.00 | $9,665 | 100.00 | $10,507 | 100.00 |
| Real estate | 8,918 | 82.85 | 8,265* | 85.51 | 8,757 | 83.35 |
| *Land* | *6,126* | *56.91* | *6,212* | *64.27* | *6,119* | *58.23* |
| *Buildings* | *2,814* | *26.14* | *2,053* | *21.24* | *2,624* | *25.26* |
| *Dwelling house* | *1,809* | *16.81* | *1,238* | *12.81* | *1,618* | *16.00* |
| Livestock | 1,386 | 12.88 | 1,091 | 11.29 | 1,323 | 12.59 |
| Machinery and tools | 326 | 3.03 | 227 | 2.35 | 305 | 2.90 |
| Cash | 97 | .90 | 67 | .69 | 80 | .86 |
| Feed and supplies | 37 | .34 | 15 | .16 | 32 | .30 |

*Landlord's capital.

Two points must be kept in mind in discussing capital used on the farm; first, the total amount and second, the distribution or the amount invested in different parts of the farm business. The farmer operating his own farm is using about $1,000 more than both tenant and landlord use on rented farms. A large part of this difference is in the buildings which are valued at $760 more on the farms operated by owners than on the rented farms. The difference in the value of the dwelling makes up the greater part of this. The investment in live stock and machinery is less on tenant farms than on those operated by owners. The percentages of total capital used for different purposes on farms operated by owners are

*U. S. Department of Agriculture—Farmers' Bulletin 635.

not strikingly different from the percentages used in the same way on tenant farms. The investment in real estate seems proportionally high. This may be partly due to high land values, however a number of the farms are not carrying as much stock as they could carry. One may have too much of the capital invested in real estate and not have sufficient capital left for operating the farm economically.

Raising colts to reduce the cost of horse labor.

TABLE VII—*Size of Farms Related to Capital Invested in Buildings, 201 Farms.*

| Size of farms (Acres) | Number of farms | Average capital invested in dwelling house | Average capital invested in all buildings except dwelling house | Percentage of capital invested in all buildings |
|---|---|---|---|---|
| 60 or less | 26 | $1,060 | $ 465 | 44.0 |
| 61 to 120 | 57 | 1,382 | 788 | 31.9 |
| 121 to 180 | 58 | 1,843 | 955 | 26.1 |
| 181 to 240 | 29 | 1,910 | 1,150 | 22.3 |
| Over 240 | 31 | 2,248 | 1,571 | 19.0 |

The farmers living on farms of 60 or less acres have 44 percent of the total capital invested in buildings; almost two-thirds of this is invested in the dwelling house. There is a general rise in the value of the dwelling house and other buildings as the acreage of farms increases. In the group of

farms with over 240 acres per farm there is but 19 percent of the capital invested in buildings and about three-fifths of this is invested in the dwelling house; still the dwelling house is worth more than twice as much as the dwelling in the group of smallest farms.

## SOURCES AND DISTRIBUTION OF INCOME.

**Profits and Number of Sources of Receipts.** There are some advantages in having the income distributed among several sources and throughout the year. There is not likely to be a failure of several crops in a given year; prices of all crops are not likely to be low at one time; when crops are growing and ripening at different periods labor can be supplied without great difficulty; disease does not commonly attack all kinds of livestock at once, and one usually spends more wisely if his money comes in a little at a time rather than in a lump sum.

TABLE VIII.—*Profits on Farms Operated by Owners and Tenants Classified According to the Number of Sources of Income over $100.*

| Number of sources of income over $100 | 158 farms operated by owners | | 43 farms operated by tenants | | 201 farms | |
|---|---|---|---|---|---|---|
| | Number of farms | Labor income | Number farms | Labor income | Number of farms | Labor income |
| 1 or none | 27 | −$195 | 11 | $ 98 | 38 | −$110 |
| 2 | 48 | −102 | 11 | 188 | 59 | −48 |
| 3 | 31 | −62 | 4 | 392 | 35 | −10 |
| 4 | 24 | 156 | 8 | 454 | 32 | 230 |
| 5 | 18 | 417 | 4 | 1,006 | 22 | 524 |
| 6 or more | 10 | 788 | 5 | 1,150 | 15 | 909 |

The labor income of the farms in the group with one or no source of income over $100, is the lowest of the various groups; the group with the largest number of sources has the largest labor income. This is true of all farms regardless of tenure. As the number of sources of income increases the labor income increases also. The increase in labor income is more rapid in passing from one group to the next when there are several sources of income over $100 than when there are but few.

**Sources of Receipts.** The farmers of Brooke County derive their incomes from the sale of crops, stock, stock pro-

ducts, and some miscellaneous receipts which are mostly for work off the farm.

TABLE IX.—*Distribution of Receipts on Farms Operated by Owners and Tenants.*

| Sources of receipts | 158 farms operated by owners | | 43 farms operated by tenants | | 201 farms | |
|---|---|---|---|---|---|---|
| | Receipts | Percent of total receipts | Receipts | Percent of total receipts | Receipts | Percent of total receipts |
| Total receipts | $1,467 | 100.00 | $1,286 | 100.00 | $1,427 | 100.00 |
| Crops | $ 195 | 13.2 | $ 249 | 19.4 | $ 206 | 14.4 |
| Livestock | 368 | 25.0 | 299 | 23.3 | 353 | 24.7 |
| Stock products | 522 | 36.0 | 447 | 34.7 | 506 | 35.5 |
| Miscellaneous | 129 | 8.7 | 150 | 11.7 | 133 | 9.3 |
| Increased inventory | 253 | 17.1 | 141 | 10.9 | 229 | 16.1 |

The largest receipts comes from the sale of stock products and the next largest from the sale of livestock. Crop sales are not usually large.

Tenants receive a little more from crops than owners operating their own farms. The same is true as regards miscellaneous receipts. The small amount of stock on tenant farms accounts for the larger crop sales by tenants.

## TYPES OF FARMS.

There are various ways of classifying farms as to type but for this discussion those having an enterprise yielding more than fifty percent of the gross receipts have been grouped together. On this basis there are 9 truck farms and 18 dairy farms among the 201 farms in Brooke County. There are a few other farms in the county which would fall into other types on the same basis but they are so few that a study of them would be unimportant for general averages.

**Truck and Dairy Farms.** There are several farms in the county selling a considerable amount of truck crops which do not fall into the class of truck farms since less than 50 percent of their receipts come from sales of truck. The same is true of farms selling dairy products.

TABLE X.—*Truck and Dairy Farms Compared.*

| Factors | 9 Truck farms | 18 Dairy farms | 201 Farms |
|---|---|---|---|
| Total capital per farm | $6,338 | $12,966 | $10,507 |
| Acres in farm | 83.2 | 167.0 | 150.0 |
| Crop acres | 32.1 | 62.1 | 55.2 |
| Value of livestock | $491 | $1,715 | $1,323 |
| Animal units | 5.9 | 24.1 | 21.6 |
| Value of machinery | $200 | $403 | $305 |
| Labor units per man | 114.0 | 175.0 | 151.0 |
| Family labor per farm | $118 | $214 | $153 |
| Family income | $894 | $1,058 | $716 |
| Labor income | $567 | $389 | $125 |

Truck crops in the Ohio Valley.

Table X shows that on the truck farms capital, size of farm, crop acres, value of machinery and family labor are about half as much as the same factors on the dairy farms. All these factors are a little higher on the dairy farms than for the average of all the farms. There is about four times as much livestock on the dairy farms as on the truck farms, and about one-third more labor. The labor income of the truck farms is about one-third larger than the labor income of the dairy farms, and about four and one-half times as large as the average labor income on all the farms.

The opportunity for trucking is limited by both soil and markets. There is a considerable area adapted to trucking which is unused and no truck crops are shipped out. Local markets are not completely supplied. Dairy products can be produced in nearly all sections but the profitableness will be

limited in many cases by the bad roads which add much to the expense.

**Farms Selling Milk, and Butter and Cream.** Of the farms with six or more cows there are 14 selling milk and 64 selling butter or cream, or both.

A method of marketing dairy products.

TABLE XI.—*Farms Selling Market Milk Compared with Those Selling Butter and Cream.*

| Factors | 14 Farms selling market milk | 64 Farms selling butter and cream |
|---|---|---|
| Capital per farm | $13,979.00 | $12,390.00 |
| Number of acres per farm | 182.00 | 167.00 |
| Number of cows per farm | 16.50 | 10.10 |
| Receipts per cow from milk and its products | $112.28 | $65.18 |
| Feed purchased per cow | 22.64 | 13.72 |
| Receipts per farm from crops | 152.40 | 172.20 |
| Crop index | 90.10 | 107.90 |
| Distance from market (miles) | 3.20 | 4.40 |
| Family labor per farm | $302.00 | $189.25 |
| Labor income | 641.00 | 136.00 |

The farms selling market milk have more capital invested, larger farms and more cows than those selling butter and cream, and the receipts per cow are almost twice as great. The difference in the receipts per cow is largely due to the difference between the value of the product when sold as

market milk or butter. The farms selling butter and cream have much better crop yields and receive more from sales of crops than the farms selling milk. The farms selling milk are closer to market, have a larger amount of family labor, and are making a labor income more than four times as large as the farms selling butter and cream.

**Receipts per Cow.** On farms with less than four cows a large percentage of the milk is used by the family. The average receipts per cow on farms with four or more cows is $66; the average receipts on farms with twelve or more cows is $84.

## FORMS OF TENANCY.

**Cash and Share Rented Farms.** Of the 201 farms studied there are 27 farms cash rented, 14 farms share rented, and 2 farms partly cash and partly share rented. A few farmers owned land and rented additional land but they are so few that they are not considered separately.

TABLE XII.—*Comparison of Farms of Different Tenure.*

| | 27 Cash rented farms | 14 Share rented farms | 43 farms operated by tenants | 158 Farms operated by owners |
|---|---|---|---|---|
| Tenant's capital | $1,434 | $1,291 | $1,399 | ..... |
| Landlord's capital | 8,613 | 7,661 | 8,265 | $10,764 |
| Acres in farm | 147 | 186 | 159 | 148 |
| Man labor units per farm | 280 | 253 | 269 | 289 |
| Productive labor units per man | 154 | 155 | 155 | 150 |
| Animal units per farm | 18.4 | 20.0 | 18.8 | 22.3 |
| Crop index | 87.9 | 92.9 | 90.6 | 104.5 |
| Cash rent per acre | $1.85 | $2.75* | $2.29* | ..... |
| Landlord's percentage on investment | 2.2% | 3.9% | 2.8% | ..... |
| Labor income | $445 | $328 | $421 | $45 |

*Equivalent to cash rent.

There is but little difference in the factors on the farms rented for cash and those rented on shares. The crop index on all the rented farms is considerably lower than on the owned farms. The men who rent for cash get the use of the farms at almost a dollar less per acre than the farmers who rent on shares. The landlords who rent their land for a share of the crops are making a higher rate of interest than the landlords who rent for cash. The landlord's rate represents the percentage that his farm income forms of his capital. The tenants who rent for cash make $117 more labor income than the tenants who rent on the share basis.

TABLE XIII.—*Variation in Rent Received by Landlords on 41 Farms Operated by Tenants.*

| Landlord's rent. Percentage on investment | Number of landlords | Percent of total number |
|---|---|---|
| 1 or less | 8 | 19.5 |
| 1.1 to 2 | 10 | 24.4 |
| 2.1 to 3 | 8 | 19.5 |
| 3.1 to 4 | 4 | 9.8 |
| 4.1 to 5 | 6 | 14.6 |
| Over 5 | 5 | 12.2 |

None of the landlords are receiving a very high rate of interest on their investments. Of the 41 landlords, 18 receive 2 percent or less, and only five receive over 5 percent.

## THE EFFECT OF ACREAGE ON DIFFERENT FACTORS OF PRODUCTION.

**Efficiency in the Use of Labor.** The farmers with a small acreage are handicapped in many of the farm operations as shown in the following tables. Almost as much machinery and motive power must be kept on hand for growing a few acres of crops as for several times as many. A large field can be worked much more economically than a small one.

TABLE XIV.—*Labor Efficiency of Farms Grouped According to the Number of Crop Acres.*

| Crop acres | Number of farms | Number of work horses | Crop acres per work horse | Man equivalent | Crop acres per man | Val. of machinery per crop acre |
|---|---|---|---|---|---|---|
| 20 or less | 28 | 1.8 | 7.0 | 1.3 | 10.2 | $10.39 |
| 21 to 40 | 42 | 2.5 | 12.2 | 1.6 | 19.6 | 5.99 |
| 41 to 60 | 52 | 3.5 | 14.5 | 1.9 | 27.0 | 5.63 |
| 61 to 80 | 43 | 4.4 | 16.0 | 2.1 | 34.3 | 5.12 |
| 81 to 100 | 18 | 5.4 | 16.3 | 2.4 | 36.7 | 5.28 |
| Over 100 | 18 | 6.2 | 19.8 | 2.8 | 44.6 | 4.60 |

Each man and horse cares for a larger number of acres of crops on the farms growing the larger acreages of crops. The difference in the number of crop acres per work animal in groups of smallest and largest farms is 12.8 and the difference in crop acres per man is 34.4. The value of machinery per crop acre is $10.39 in the group of farms with twenty acres or less. In the group 21 to 40 acres the value of machinery per crop acre is $5.99. There is not a great change in the value of machinery per crop acre in the groups of farms with larger crop acreages.

**Yields of Crops.** About nine-tenths of the farmers grow corn and hay, about eight-tenths grow oats and about one-half grow wheat.

TABLE XV.—*Yields of Crops on Farms of Different Sizes.*

| Size of farms (Acres) | CORN | | OATS | | WHEAT | | HAY | |
|---|---|---|---|---|---|---|---|---|
| | Number of farms | Bushels per acre | Number of farms | Bushels per acre | Number of farms | Bushels per acre | Number of farms | Tons per acre |
| Average | | 42.0 | | 28.3 | | 12.0 | | 1.00 |
| 30 or less | 7 | 44.0 | 2 | 9.8 | .... | ..... | 5 | 1.20 |
| 31 to 50 | 7 | 39.6 | 5 | 17.8 | 2 | 10.0 | 7 | 1.10 |
| 51 to 100 | 41 | 35.8 | 30 | 22.5 | 14 | 15.2 | 42 | 1.00 |
| 101 to 150 | 42 | 40.7 | 41 | 25.8 | 22 | 11.2 | 41 | .98 |
| 151 to 200 | 43 | 41.0 | 42 | 29.6 | 30 | 12.3 | 45 | 1.00 |
| Over 200 | 43 | 44.3 | 42 | 30.8 | 37 | 12.0 | 43 | 1.00 |

The old method of using the corn crop.

There seems to be no direct relation between size of farms and crop yields except in the case of oats which shows a gradual increase in yield as the number of crop acres increases.

**Expenditure of Labor.** Some types of farming require much more labor per acre than other types, however, labor can be more economically used on large general farms properly organized than on small farms of the same type.

**Intensity of Livestock Production.** An animal unit represents one horse, cow or the equivalent, based upon the amount of feed eaten.

TABLE XVI.—*Relation Between the Amount of Livestock kept per 100 Acres of Pasture and Crop Land, and Labor Income, 192 Farms.*

| Number of farms in group | Number of animal units per 100 acres of crop and pasture land | Average number of animal units per 100 acres of crop and pasture land | Labor income |
|---|---|---|---|
| 34 | 10 or less | 6.5 | $ 2 |
| 53 | 11 to 15 | 13.2 | 18 |
| 49 | 16 to 20 | 17.8 | 120 |
| 33 | 21 to 25 | 22.5 | 169 |
| 23 | Over 25 | 32.3 | 328 |

The amount of livestock to be kept on a given area of land is determined by many factors, such as productivity of soil, relative value of crops and stock, and amount of labor avail-

The new way; increasing in popularity.

able. In this study truck farms have been omitted since livestock is not a large factor in that business. The farmers who have farms in condition to carry a reasonable amount of stock are making larger labor incomes than those who can keep only a few head on an equal area of crop and pasture land. Table XVI shows clearly that it pays to have land in condition to carry more stock than many farms now carry. The labor income increases in each group of farms from those having ten or less animal units per hundred acres of crops and pasture up to those having twenty-five or more animal units on the same area.

## LAMB PRODUCTION.

Fine-wool sheep—Merinos and Delaines—are practically the only breeds grown in Brooke County. Wool production has been one of the leading industries for many years. Since the price of wool has become very low, fine wool sheep are not so profitable as formerly. The fleeces average 6.8 pounds; the price this year averaged 23.5 cents per pound.

A profitable method of using pasture some distance from market.

TABLE XVII.—*Lamb Production on Farms with Different Numbers of Ewes.*

| Ewes per farm | Number of farms | Average number of ewes per farm | Number of farms reporting lambs | Average number of lambs per ewe |
|---|---|---|---|---|
| 50 or less | 28 | 26 | 21 | .38 |
| 51 to 100 | 22 | 71 | 19 | .35 |
| Over 100 | 16 | 140 | 14 | .29 |

From Table XVII it will be seen that some of the farmers raise no lambs at all some years. Of 66 farmers who kept ewes but no wethers, 12 report no lambs. The farmers who grow lambs are not attempting to grow very many. The average is about one-third of a lamb per ewe.

## EGG PRODUCTION.

Almost all farms in Brooke County grow some chickens and sell some eggs; many of them sell both chickens and eggs.

TABLE XVIII.—*Production and Value of Eggs and Chickens on Farms Having Different Numbers of Hens.*

| Number of hens per farm | Number of farms | Average number of hens per farm | Receipts for eggs | Receipts for chickens | Total receipts per hen |
|---|---|---|---|---|---|
| 50 or less | 62 | 39.6 | $ 36.25 | $17.76 | $1.36 |
| 51 to 100 | 102 | 80.8 | 81.94 | 26.80 | 1.36 |
| Over 100 | 34 | 164.0 | 163.44 | 53.97 | 1.33 |

The receipts for eggs are nearly three times as great as the receipts from sales of chickens. The receipts from both eggs and chickens are in proportion, in a general way, to the number of chickens kept. The receipts per hen are practically the same in the flocks of different sizes.

## FARMS WITH OVER $500 LABOR INCOME.

Thirty-eight farmers made over $500 labor income; of these, 14 were tenants and 24 owners. About one farmer in each five is making a labor income of $500 or more. Three farmers make over $2,000 labor income.

## AGE OF FARMERS.

The average age of the 201 farmers is 50 years. The tenants average about 10 years younger than the owners who are operating farms. Young men are generally making better labor incomes than older men, many of whom have retired from active work.

## SUMMARY.

The results of this survey show what may be expected from farming under conditions similar to those in Brooke County. The average labor income of the 201 farms is $125. In addition to this the farm has furnished a home for the family and products for the table such as milk, butter, eggs, vegetables, and meats. To be a business success a farm must pay all expenses, interest on the investment and wages for all labor performed by the farmer and his family; but a farm may be a success when it furnishes a home and a living, and gives pleasure to the owner.

**Size of Business.** We have seen that when labor income is compared with magnitude of business, when the latter is measured either by the area in crops, by the amount of productive man labor, or the gross income, the labor income increases materially as the magnitude of the farm business increases. By comparing amount of working capital with labor income we get a similar result. In order to secure an income that will permit a satisfactory standard of living, the farm business must be of considerable size. Where the situation permits very intensive farming, such as trucking, fruit growing, etc., a large business may be conducted on a few acres; but where the conditions are such as to require general farming, as most kinds of livestock farming, the acreage must be larger. A farmer with a very small acreage who cannot engage in intensive farming because of a lack of markets for the products would find it to his advantage to rent additional land or, in some cases, to sell his small farm and invest his capital in the necessary work stock and implements to farm a larger area and become a tenant on a farm of sufficient size to give an opportunity to earn a good income.

**Capital.** There is a close relation between the amount of capital invested and the family income, but on many farms where the capital is large, organization is poor and there is no income for labor.

**Diversity.** Diversified farming offers the best opportunities when carried on with a large business. The labor income rises as the number of sources of income increases as shown in Table VIII. Diversity in general farming is very important as it insures a more nearly uniform income from year to year. It also affords an opportunity for utilizing labor and machinery economically.

**Types.** Most of the farms of Brooke County are classed as general farms and have different problems from the specialized ones. Truck and dairy farms are the two specialized types most common and both are generally successful. A combination of enterprises including dairy, truck, fruit or general crop farming organized to suit individual needs seems to be most desirable. Only a small part of the area adapted to growing truck crops is utilized for that purpose at present. While there are but few large orchards, fruit of an excellent quality can be grown throughout the county. The production of dairy products need be limited by the market only. Corn for grain is giving way to silage corn and alfalfa is increasing in acreage very rapidly.

**Livestock.** While there is a great variation in the production of dairy cows on different farms, there is no striking difference in production in the groups of farms of different sizes nor in the small and large herds. The form in which the product is marketed has a considerable influence on the value of the product per cow—market milk paying best. Beef cattle are not raised in any considerable numbers. Fine-wool sheep—Delaines and Merinos—are grown almost exclusively. The size of the flock has but little influence on the production per ewe. Almost every farm has a flock of chickens. The production per hen is about the same in different sized flocks.

**Tenure.** The labor income on farms operated by tenants is larger than on farms operated by owners, but the tenant's capital is small and his income available for use of the family is smaller than that of the owner operating his own farm. Share renting usually gives the owner a larger return on his investment than cash rental.

**Opportunities and Suggestions.** A farm which gives a labor income of $500 in addition to furnishing a home and a large part of the living is a good business. While the number making this labor income is not large, about twenty percent, indications are that opportunities are open for farmers on well organized farms in this county.

Since truck and dairy farming are the most profitable types and a rather large area is available which is adapted to these industries, they can be materially increased. Markets for the products will be the first limitation. So far as can be seen now there is little danger of over supplying the markets that can be reached.

The farms some distance from the railroads or trolley lines can produce butter at a profit if good producing cows are kept, and in addition many of these farmers would find it profitable to gradually develop purebred herds from which they might sell surplus stock.

General farming is profitabe only when conducted on a large scale. The size of business may be increased by intensifying the culture or by increasing the area of the farm. The area can be extended by buying or renting additional land.

Brooke County is admirably adapted to sheep grazing. A few of the farmers have found it profitable to cross the fine-wool ewes with mutton type sires, thus producing market lambs in addition to wool. In any case it is highly desirable to produce a larger number of lambs from the ewes. The production on the average of one-third of a lamb per ewe is certainly unprofitable with present prices for mutton. (Table XVII).

Poultry is produced on almost every farm and in most cases could be profitably grown in greater numbers. The returns per hen indicate that better care of the poultry would be profitable (Table XVIII). For the man with small capital, tenant farming seems advisable. One should have enough money on hand to operate the farm economically. This year (1914) cash rental paid better for the tenant than the landlord; with poorer crops, share rental might pay better. There are some farmers in each group of farms who are making a success of their farming. This indicates that organization and management as well as the type of farm are of great importance.

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West Virginia University
Agricultural Experiment Station
MORGANTOWN, W. VA.

Department of Plant Pathology

# APPLE RUST

## TECHNICAL BULLETIN

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N. J. GIDDINGS and ANTHONY BERG

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Ben Davis Apples, Showing Effects of Cedar Rust Infection.

# APPLE RUST

## INTRODUCTION.

The apple rust, or cedar rust as it is frequently called, is a common disease in most sections where apple trees and cedar trees are growing in close proximity. Before the habits of this fungus were very well understood it was a common practice to plant a row of red cedars along one or more sides of an orchard, to serve as a windbreak. The old time mixed orchard was likely to contain varieties which showed different degrees of susceptibility and, if the rust was present, those trees which suffered most from the disease were probably considered to be weaklings. Some of the trees were practically certain to bear well, which meant enough fruit for home use, and that was the principal object of such an orchard.

When people began to realize that there was good profit in growing apples for market they found that it was an easier proposition to handle a large number of trees of one or two varieties than a few trees each of several varieties. Certain apples were soon found to be well suited to a given section or sections of the country, and specialization set in. It happened that some varieties of apples especially susceptible to the apple rust disease were chosen as desirable for the planting of commercial orchards in sections of the country where red cedar was particularly abundant. (Plate IX, figs. 1 and 3.) Under such favorable conditions it must be expected that the amount of disease would increase.

In 1910 this rust was very severe in the eastern section of West Virginia and in 1912 the fruit loss, due to rust, in one county was estimated at not less than $75,000.00. This Department began some studies of the apple rust disease in 1910. Attention has been largely devoted to economic phases of the question, since it was of such great importance in this state.

NOTE: Mr. D. C. Neal, assistant plant pathologist during 1911-13, was associated with some of this work during the seasons of 1912-13.

## HISTORICAL.

*Gymnosporangium juniperi-virginianae* was discovered and named by Schweinitz in 1822. The genetic connection between this and the *Roestelia pirata* of apple appears to have been finally worked out by Thaxter* in 1886. Since that time there have been numerous experiments dealing with the various phases of the cedar and apple rust problem. Of these, we will briefly mention the more important ones which have a bearing on the work conducted by this Station.

Halstead (1889, p. 380) says, "Very likely some varieties of cultivated apples are more susceptible to the rust than others, but as the observations upon this point are very meagre and fragmentary, it is not safe to draw general conclusions from them."

Galloway (1889, p. 413) reports on a spraying experiment for apple rust control at Vineland, N. J., in 1888. He states that the foliage remained fairly healthy, yet the benefit was not sufficient return for the labor expended.

Jones (1891, p. 139) conducted an experiment near Burlington, Vermont, in 1889. The trees were sprayed with ammoniacal copper carbonate May 17th and May 30th. The results showed no marked difference in the percent of rusted leaves, but the number of rust spots per rusted leaf were less on the sprayed than on the unsprayed trees.

Pammel (1891, p. 43) sprayed trees of the wild crab apple with Bordeaux mixture and ammoniacal copper carbonate. He concluded that there was little benefit from spraying.

Jones (1892, p. 133) reported on further experiments in the control of apple rust by spraying. He secured fairly good results, but did not feel that this method of control was very practical.

Jones (1893, p. 83) reported on the destruction of cedars as a means of controlling apple rust. He states that, "in the fall and winter of 1891-92 the red cedars were all destroyed in this orchard, and for a radius of one mile around a careful examination was made and every cedar found was uprooted. The result was magical. In former years many of the apple trees were entirely defoliated by rust in August; the past summer not a rusted leaf was found in the entire orchard. The

*This statement is based on Halstead, 1889, p. 375.

moral is plain. Red cedars should not be allowed to grow in or near an apple orchard. From the scientific standpoint the result is interesting as indicating that the mycelium of this fungus is not perennial in the apple, and that the occurrence of the rust on the apples is dependent upon annual reinfection from the red cedar." It should be noted, however, that the red cedar is not reported as a common tree in Vermont. While the trees were all destroyed within a range of one mile of this orchard, it is quite likely that very few of them could have been found within a radius of two miles.

Stewart and Carver (1896, p. 538) carried on a series of experiments to ascertain why the cultivated apple in central Iowa should be free from *Roestelia*. Inoculations with *G. juniperi virginianae* were made upon the wild crab, *Pyrus Coronaria*, and upon cultivated varieties at Ames, Iowa, and Long Island, N. Y. Abundant *Roestelia* developed on the wild crab but in no case was it formed on the cultivated varieties inoculated at Ames. The experiment at Long Island gave evidence that some varieties were wholly exempt from *Roestelia*, which indicated that its absence on cultivated apples in Iowa might not be entirely due to unfavorable weather conditions, but chiefly to the fact that the varieties grown in Iowa were not susceptible.

Austin (1901, p. 296) carried out the following spray program: Trees were carefully sprayed March 24th before growth started, again April 25th, May 4th, May 22nd, June 5th, June 20th, July 23rd, August 9th and August 28th. On October 10th the trees were examined and it was found that they were at least as badly infected as in the previous year.

Emerson (1905)* reports the results of a detailed spray program. Twenty-two trees of the variety Wealthy, and eight of Jonathan received from one to three applications of Bordeaux. The dates of spraying were April 26th, April 27th, May 7th, May 9th, May 23rd, and May 28th. Trees which were sprayed on May 7th or May 9th showed remarkable control.

Heald (1907, p. 219) discovered the biennial character of the fungus on the red cedar. He also carried out a series of spraying experiments to control the rust on cedar trees, and some very good results were secured.

*These statements in regard to Prof. Emerson are based on Pammel's report in Nebraska Agr. Exp. Sta. Bulletin 84, "The Cedar Apple Fungi and Apple Rust of Iowa," page 34.

Hein (1908) says, "Although spraying with Bordeaux mixture or other fungicides is sometimes recommended as a treatment for rust, we have experimented for three years without any markedly beneficial results."

Stewart (1910, p. 194) reports that Mr. F. A. Sirrine at Long Island has usually had little success in controlling rust in his bearing orchard by several applications of Bordeaux. However, in 1910, trees given two applications of 3-3-50 Bordeaux showed only one-tenth as much rust as the unsprayed trees.

Giddings (1911, p. 3) reports a case in which rust was well controlled by a single spray application.

Coons (1912, p. 217) carried on some experiments as to the development and discharge of sporidia. Speaking of the teliospores, he states that "The process of putting out germ tubes requires from 6 to 15 hours", but in our work we have secured **abundant sporidia discharge** within less than 3 hours after a sorus was moistened for the first time. (Plate II, figs. 1 and 2.)

Reed, Cooley & Rogers (1912, p. 7) state that various spray materials are being tried for control of rust, but that no entirely satisfactory spray has been found up to the present time. The same authors (1912 a) found that transpiration and carbon dioxide assimilation were greatly retarded in apple leaves which were infected with rust.

Bartholomew (1912, p. 253) reports the results of experiments for the control of this rust by spraying. Applications of Bordeaux mixture were made on May 15th, May 22nd and May 30th. He states that the spraying was done, "immediately following the formation on the cedar galls of the jelly-like telial extrusions," and "before sufficient time had elapsed for the transfer of the sporidia from the galls to the apple foliage." The trees so sprayed showed pronounced decrease in the percent of infected leaves. He concluded that, "The proper time for spraying cannot be designated by any fixed dates, for the crucial time for action depends entirely upon such weather conditions as favor the development of the cedar galls."

Giddings and Neal (1912, p. 258) found it possible to control this rust by spraying with lime-sulphur, Bordeaux mixture, or atomic sulphur.

Fulton (1913, p. 62) carried out some experiments on infection of apple leaves by rust. He concludes that, "Each leaf is most susceptible during a brief period only, in its development, and that at younger and older stages it is less susceptible or entirely immune." He says, "From the first swelling of the gelatinous horns to the formation of infection spores about 24 hours of moisture are required," but this must be an error since we have records of abundant sporidia discharge, under normal field conditions, within 6 to 8 hours after it first began to rain. (See page 14.)

Reed, Cooley and Crabill (1914) secured good results by spraying, but concluded that it was far more practical to destroy the cedar trees for ½ mile around orchards. They found a copper-lime-sulphur spray to be especially effective. This publication also states that, "The apple leaf is only susceptible to infection with cedar rust during its early period of development." They report a continuous discharge of sporidia for more than five days after a rain, but this hardly seems possible.

Reed and Crabill (1915, p. 180) report that respiration is increased in leaves which are infected with *Gymnosporangium.*

## DISTRIBUTION.

This rust appears to be widely distributed through the central and eastern portions of the United States, and has been found in Ontario, Canada.

Rust on apple species has been reported from the following states:

Alabama
Arkansas
Colorado
Delaware
Dist. of Columbia
Florida
Georgia
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Nebraska
New Jersey
New York
North Carolina
Ohio
Oklahoma
Pennsylvania
Rhode Island
South Carolina
South Dakota
Tennessee
Vermont
Virginia
West Virginia
Wisconsin

## DESTRUCTIVENESS.

As previously stated this disease has caused enormous losses to fruit growers in West Virginia. It was especially destructive in 1912 and the crop of York Imperial apples was an entire failure in many orchards. The trees were well loaded with fruit, but it was of such inferior quality that it hardly paid for the cost of picking. Actual fruit losses ranging from $2,000.00 to $3,000.00 per orchard, and due entirely to rust, were very common through the eastern portion of the state that season, while there were many smaller losses and some larger ones.

The injury resulting from apple rust is apparent in three ways: 1. The loss due to infected fruit. 2. Decreased size of fruit. 3. Loss of vigor of tree. Nearly all of the fruit infections take place in the calyx end, and this is not surprising in view of the fact that the apple is inverted, calyx end up, until about one month after blooming, and but comparatively few rust spores are disseminated after that time. During the time that the apple is in this inverted position the sporidia of the rust fungus find easy lodgement in the depression around the calyx or even in the so-called calyx cup, and moisture readily collects there so that conditions for their germination are almost ideal. Many diseased fruits find their way into the barrels, but they are more likely to be seconds than firsts, and a considerable number are so deformed as to be thrown in with the culls. (See frontispiece.) A large proportion of rusted fruits become infected with secondary rot fungi, and this entails much loss.

A question soon raised by apple buyers was whether or not the disease would spread in storage. While we were certain that it did not spread, no statements could be found in regard to it. In order that we might cite definite evidence along that line the following series of experiments was conducted:

A box was packed with 164 Ben Davis apples, 59 of which were rusted fruits, scattered among the healthy ones. In another box 57 rusted Ben Davis apples were mixed with 132 sound Rome apples. A third box was packed with 30 Rome, 23 healthy Ben Davis, and 53 rusted Ben Davis apples. The healthy Ben Davis and Rome apples were wounded with a sterile knife and a rusted Ben Davis was placed with the

diseased portion in contact with the wounded spots on the healthy apples. In a fourth box were packed 10 Ben Davis and 18 Rome apples each of which had been inoculated by placing a mature aecium in a slit in the flesh. In still another box were placed 31 rust diseased apples which showed no indication of aecia, and in the same box were packed 25 apples which had partially developed aecia. The surface areas of the rust spots on about 50 of these apples were marked off with india ink. All of the boxes were placed in cold storage at about 34° to 38° F.

The apples were placed in storage the 26th of November, 1910. They were examined January 31st, 1911, and May 18th, 1911. There was no indication of any vital activity on the part of the rust. No additional fruits developed rust; no aecia had developed; there was no change in appearance of partially developed aecia; and no increase in surface area on infected fruits. Cutting open such diseased apples, there was in many cases, a brown, somewhat corky layer surrounding the rust diseased tissue. There was considerable evidence of the activity of secondary fungi attacking the apples by way of these rust spots.

Other boxes of apples prepared and handled in the same way as those just described were placed in storage at 40° to 50° F. and the results were similar except that a greater amount of rot developed.

The second way in which the loss from rust becomes apparent is through the decreased size of fruits. In the case of infections which are at all severe the size of all the apples, sound as well as rusted, is reduced very appreciably. (Plate V, fig. 3.) More detailed statements in regard to this phase of the disease will be given under another heading.

The third injurious effect noted in diseased trees is the weakened vigor of the tree itself. This effect may persist to a very noticeable extent for at least two seasons after a serious outbreak of rust. It will be dealt with in more detail on another page.

## PLATE I.

Fig. 1—Rust gall of *Gymnosporangium juniperi-virginianae* on red cedar, with mature teliosori. These sori have never been moistened. (About ⅔ natural size.)

Fig. 2—Same gall as shown at right in Fig. 1, but after moistening for about 3 hours. (About ⅔ natural size.)

Fig. 3—Mature teleutospores with pedicels. (× 240).

Fig. 4—Teleutospores taken 1 hour and 20 minutes after first moistening. Note early development of promycelium. (× 240).

Fig. 5—Teleutospores taken 1 hour and 45 minutes after first moistening a sorus. The promycelium is well developed. (× 240).

Fig. 6—Teleutospores taken 2 hours and 15 minutes after first moistening a sorus. The promycelium has divided into four cells with distinct walls and nuclei. (× 240).

## LIFE HISTORY.

*Gymnosporangium juniperi-virginianae* is a heteroecious rust having the red cedar, *Juniperus virginianae*, and species of apple, *Malus*, as hosts. On the red cedar it appears in the form of corky galls, commonly known as "cedar apples." (Plate III, fig. 5.) In this latitude the galls first become apparent during June, continue to grow through the summer, and have almost reached maturity by late autumn. With the first warm weather of spring they develop numerous brownish projections known as sori. (Plate I, fig. 1.) Each sorus is composed of numerous two-celled teliospores more or less imbedded in a gelatinous matrix. (Plate I, fig. 3.)

Under favorable weather conditions, with sufficient moisture, these sori swell into large, finger-like projections. Each cell of a teliospore may then send out a promycelium. This promycelium quickly divides into four cells, each of which produces a secondary spore or sporidium. (Plate I, figs. 4 to 6.) As soon as the humidity decreases enough to cause appreciable evaporation the sporidia are forcibly discharged as stated by Coons (1912, p. 230)*.

The teliospores do not all germinate at once and sporidia may be discharged several times during the season. They are readily carried about by air currents and deposited on the

*The forcible ejection of sporidia was independently observed by the senior author during the spring of 1912. In a number of cases it was noted that there was an abrupt sidewise movement of the sporidium several seconds previous to its discharge. This movement was believed to indicate the rupturing of an outer wall or membrane at the base of the sporidium, but the studies were not made in sufficient detail to warrant any general conclusions.

1
2
3
4
5
6

## PLATE II.

Fig. 1—Teleutospores taken 3 hours after first moistening a sorus. Note sporidia formation. (× 240).

Fig. 2—Sporidia discharged upon slide 3 hours and 15 minutes after first moistening. (× 240). In several instances there was abundant discharge in less than 3 hours, but photographs were not secured.

Fig. 3—Mature rust spots on apple leaf. Upper surface view. (Reduced.)

Fig. 4—Upper surface of rust spot on apple leaf 16 days after inoculation. Note exudate from pycnia. (× 11.5).

Fig. 5—Upper surface of rust spot on apple leaf 20 days after inoculation. Exudation has ceased from most of the pycnia and they have turned black. (× 11.5).

Fig. 6—Pycniospores. (× 240).

foliage of any nearby apple trees. Sporidia which find their way to the young foliage or fruit of susceptible apple varieties, under favorable weather conditions, will germinate and enter the host tissues.

The rust spots first become visible upon the upper surface of the leaves, and in about ten days after infection has taken place.*

At this time they are pale yellow spots about the size of a pin head. They assume a darker shade of yellow as they enlarge. (Plate II, fig. 3.) On some of the more susceptible varieties these spots sometimes become half an inch in diameter by the end of the season.

In about two weeks after the first appearance of the spots, little raised specks appear near the center of them. (Plate II, fig. 4.) These are the openings of the flask shaped pycnia. The sticky, dark orange exudate which may be seen on the rust spot at about this time contains the pycniospores. (Plate II, fig. 6.) As far as is known they have no important bearing on the life history of this fungus. Soon after the pycniospores have been discharged, the pycnia become apparent as small black spots. (Plate II, fig 5.)

On the lower surface of the spot, hypertrophy takes place, producing a swelling considerably elevated above the normal

*Our records show that inoculation made April 14, 1913, gave clearly visible spots in 16 days, while the infection which took place May 15th produced spots in 12 days. In 1914, the April 26th infection became apparent in 11 days and visible spots developed from the May 5th infection in 9 days.

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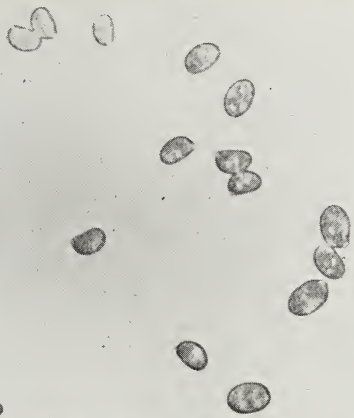
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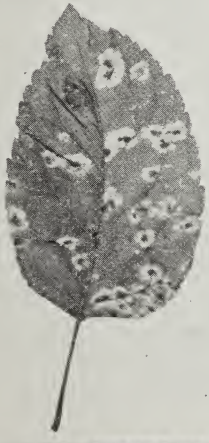
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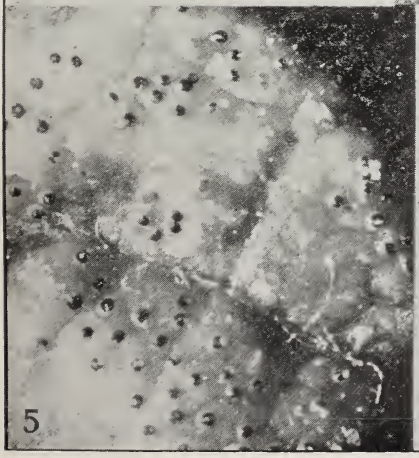
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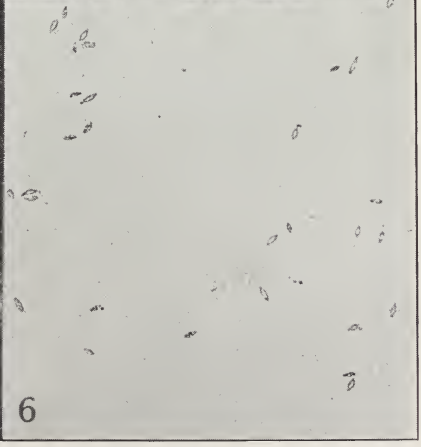
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## PLATE III.

Fig. 1—Mature rust spots on apple leaf. Lower surface view. (Reduced.)

Fig. 2—Young aeciosori. Taken 64 days after inoculation. (× 5).

Fig. 3—Mature aeciosori. They are open and many of the aeciospores are gone. (× 11.5).

Fig. 4—Aeciospores. (× 240).

Fig. 5—Cedar twig with numerous galls of various sizes.

leaf surface. During the months of July and August bodies known as cluster cups, which bear the aeciospores, break through these swellings. (Plate III, fig. 2.) The aeciospores of this fungus are not capable of producing reinfection of the apple, but may be carried back to the cedar where they lodge in the axils of the tiny leaf scales, producing an infection in the young growth of the cedar. No outward indication of such cedar infection can be observed until the following season.

## CONDITIONS INFLUENCING INFECTION OF APPLE.

It was believed that a more definite knowledge of the conditions which bring about rust infection of the apple under field conditions would be of value, and some attention has been devoted to this matter. These conditions readily fall under four main heads:

1. Development of rust galls on the cedar.
2. Meteorological conditions.
3. Development of apple foliage.
4. Location of orchard in relation to cedars.

The normal rust galls of *G. juniperi virginianae* as they occur on the red cedar in West Virginia are capable of discharging large numbers of sporidia at almost any time from the first of April to the first of June. This period varies considerably with different seasons, but the fruiting bodies are always well developed by the time that the apple buds begin

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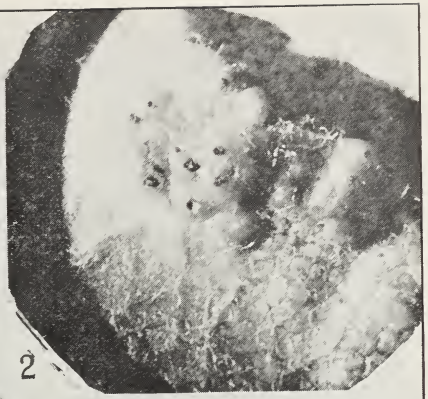

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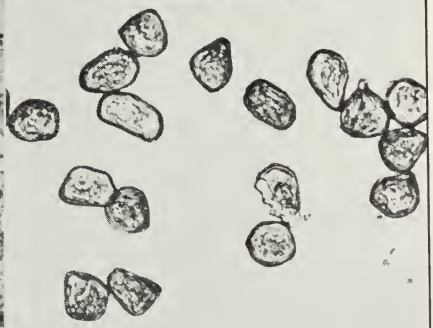

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to open, and slight rust infections often occur as late as the first week in June.

The ability of the rust galls to produce and discharge sporidia is closely associated with meteorological conditions. Considerable difficulty was experienced in our endeavors to accurately determine the interrelation of meteorological factors with infection periods. Some general notes were made as to weather conditions during the season of 1912. These records were as good as could reasonably be secured under the circumstances. Data covering the critical period for that season shows that there was fair weather from the first to the fifth of May, a light shower on the afternoon of May 5th, fairly heavy rains from the afternoon of May 6th to the afternoon of May 8th, and fair weather from the 9th to the 11th. The important rust infection for 1912 took place between the evening of the 6th and the afternoon of the 8th of May. There was a slight earlier infection and another about the last of May or the first of June.

During the season of 1913 a barograph and a hygrothermograph were added to our meteorological equipment. (Plate IX, fig. 2.) This gave us a continuous record as to the temperature, humidity, and atmospheric pressure. Cold, rainy weather was prevalent most of the time from April 10th to 16th and considerable numbers of sporidia were discharged on the 13th. The recording instruments were not set up until April 14th so that we do not know the exact thermal and moisture conditions associated with the spore discharge on that date. It might be noted that there were very few apple leaves infected at this time and this is readily accounted for by the fact that measurements of a number of buds in different sections of the orchard on April 15th showed their average length to be only ⅜ inch to ½ inch.

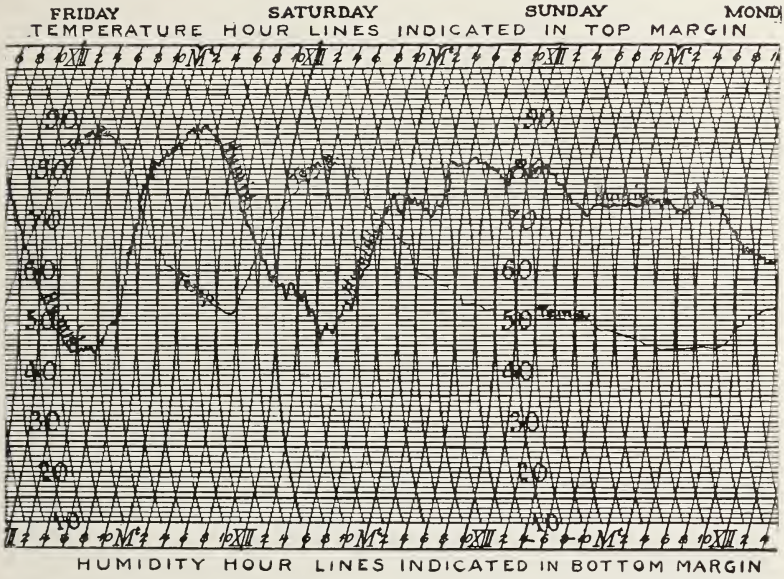
April 18th there was a thunder shower, but this had little effect on the cedar galls.

York Imperial apple trees were in full bloom April 25th and 26th.

April 27th there was an intermittent rain throughout the day and there had been some the preceding night, but there was no evidence of sporidia discharge or apple leaf infection as a result. The relatively low, and decreasing temperature which prevailed during that day and until ten o'clock the

next morning, may have prevented sporidia discharge, until the sori had dried up sufficiently to hinder it.

A section of the chart showing humidity and temperature for that period is reproduced below:



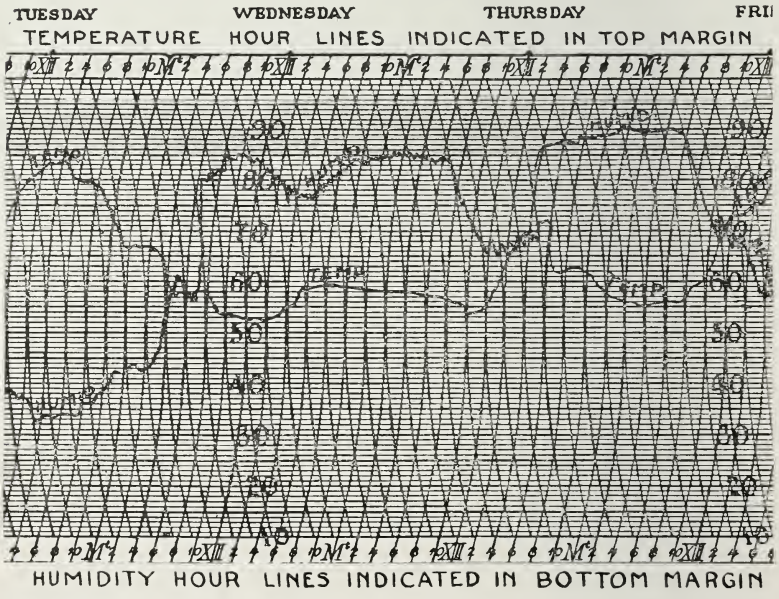

Hygrothermograph record from Friday, April 25th to Monday, April 28th, 1913.

There was no more rain until the morning of May 14th but it continued for about three to five hours at that time. In the afternoon it was cloudy and sporidia were discharged from the cedar apples in great numbers. White cards exposed just below good sized rust galls showed a very distinct yellow coating in two hours. There was no evidence of apple infection as a result of the sporidia discharge which took place that afternoon. Twigs of York Imperial apple trees that were covered with sacks on the morning of May 15th were as well protected from the rust as others right beside them which were sacked on the 14th. Conversely, twigs which had been previously sacked for two weeks to exclude rust infection and which were uncovered on May 14th, showed no more rust than similar twigs uncovered on the 15th. This can only be accounted for by the quiet condition of the air during the afternoon of May 14th. In the weather records covering that day it is stated as impossible to detect any air

stirring during the afternoon. It should be noted that these apple trees were within ten rods of large cedars which were literally loaded with rust galls.

It rained again during the night of May 14th-15th, and there was abundant sporidia discharge from about 10 A. M. to 2 P. M. of the 15th. The only serious rust infection for the season of 1913 occurred at this time. There was a light wind and it was somewhat variable.

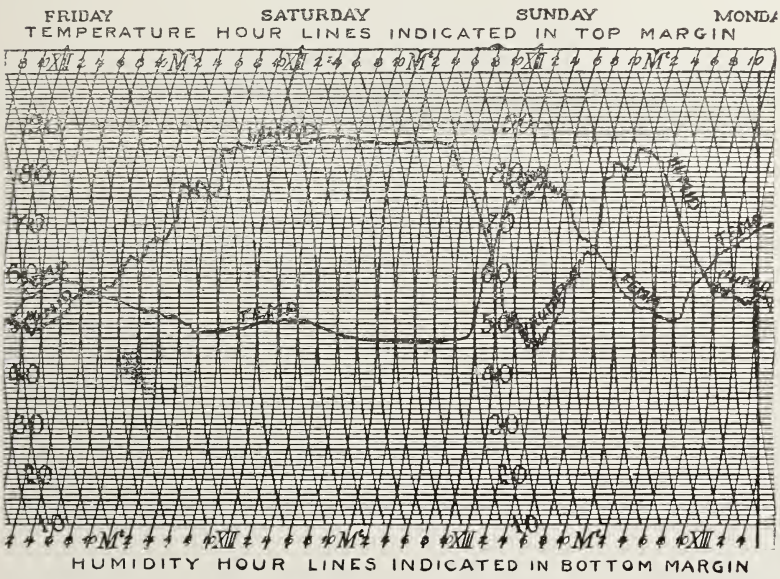
The humidity gradually dropped about 15% during the period of the most active sporidia discharge on May 14th, and there was a slight raise in temperature during that period. Similar data may be noted on the chart for May 15th, except that the drop in humidity was considerably greater and the rise in temperature was more pronounced than on the previous day. A section of chart showing tracings for May 14th and 15th, 1913, is shown below:




Hygrothermograph record from Tuesday, May 13th to Friday, May 16th, 1913.

Rain occurred again on May 17th, but there was no evidence of infection following it. Twigs which had previously been sacked and were uncovered on the 16th were as well protected as those uncovered on the 19th. The humidity and

temperature conditions would appear to have been very good for sporidia discharge, but we have no records as to air movements. It is possible that many sporidia were set free and that they settled quickly to the ground as on May 14th, but it is far more likely that only a very few were discharged, since the sori on the cedar galls were much reduced in size and evidently becoming exhausted. Careful observations as to actual spore discharge were not made on this date. The section of chart for May 17th and 18th is given below:




Hygrothermograph record from Friday, May 16th to Monday, May 19th, 1913.

Local showers occurred on the 21st and 22nd, but were of short duration, and did not have much effect on the cedar galls. May 23rd there was rain all day, but the hygrothermograph records covering that date are incomplete, and no special observations were made as to discharge of sporidia. It is worthy of note, however, that there was a light west to northwest wind recorded for the 23rd and 24th and our sacking experiments gave strong evidence that no infection took place on these dates.

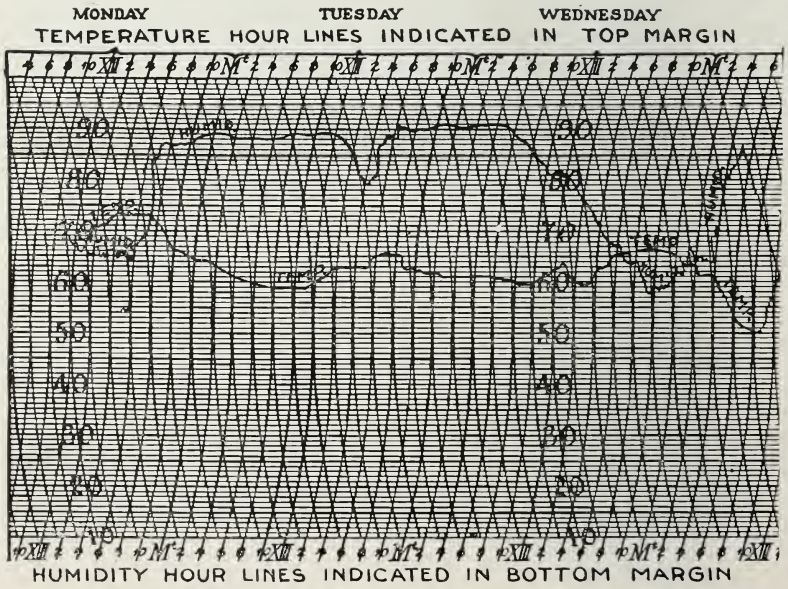
It began raining again on the evening of May 26th and continued most of the time during that night and the next day A very considerable number of apple leaves became in-

## PLATE IV.

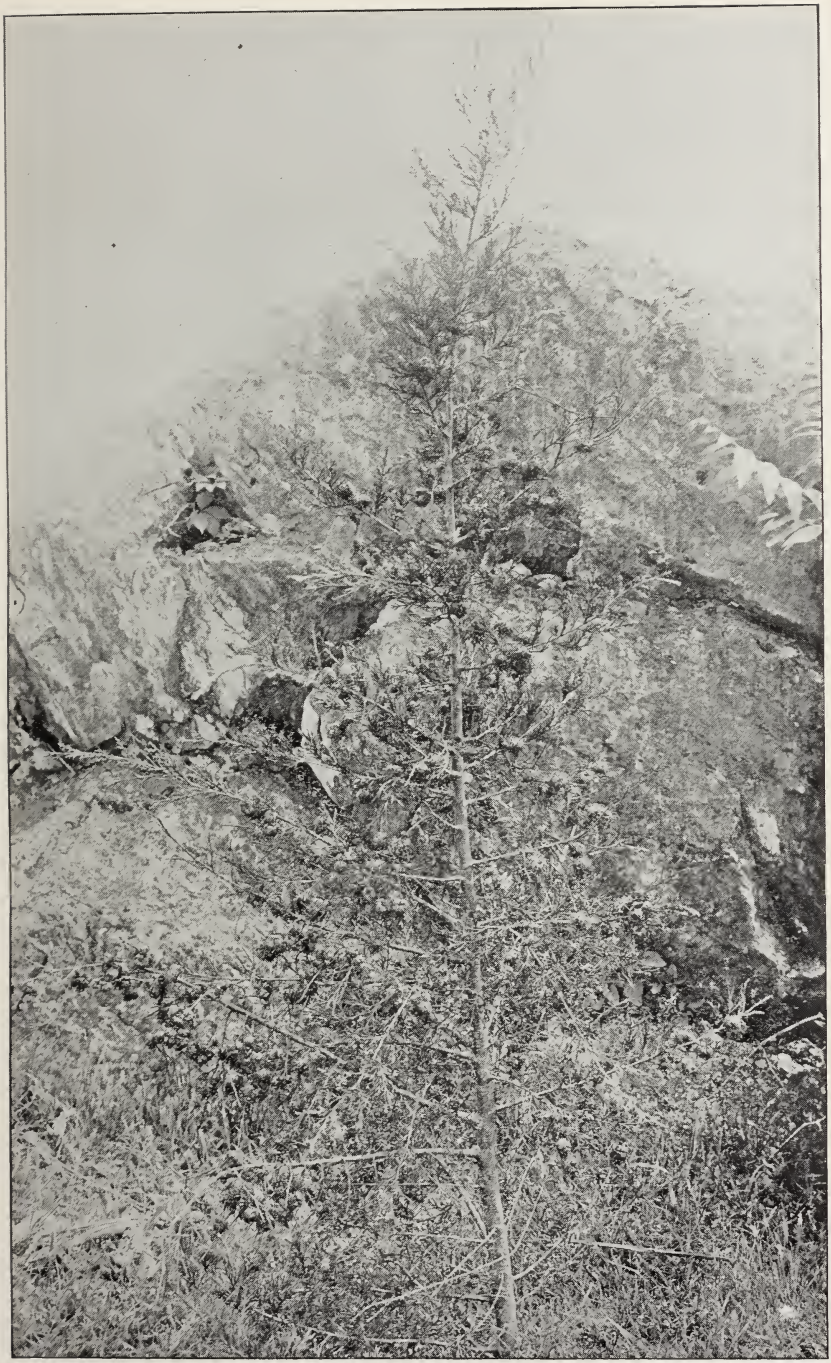
Cedar tree bearing a great number of good sized galls.

---

fected with rust on the 27th and possibly a few received infection on the 28th. It is believed that the principal and possibly the only sporidia discharge took place between 4 and 7 P. M. on Tuesday, the 27th. A drop in humidity and a rise in temperature will be noted for that period in the chart below:



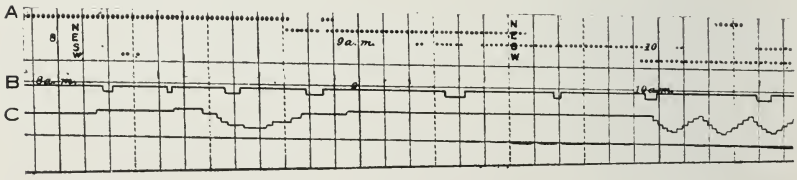

Hygrothermograph chart from Monday, May 26th to Thursday, May 29th, 1913.



Practically all of the sori dried up and dropped off from the cedar galls soon after this date and no further observations were made on them.

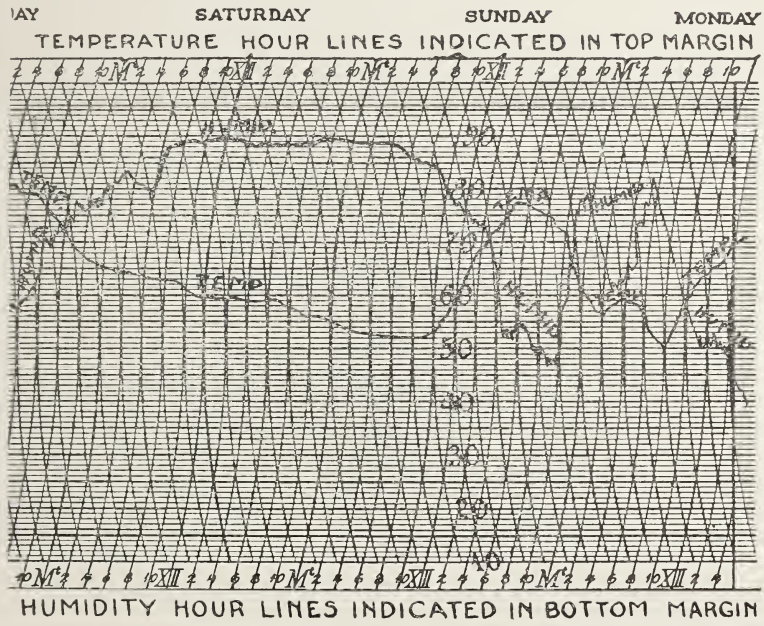
The importance of the wind in dissemination of rust, and the difficulty of making accurate observations along this line, was clearly shown by the work during 1913. In order to secure such data our meteorological equipment was again increased by securing a quadruple register, tipping bucket rain gauge, electric sunshine recorded, anemometer, and wind vane. (Plate X.) This outfit gave almost continuous records as to rainfall, sunshine, wind velocity and wind direction. The practical data secured with the aid of these instruments during the past season is very valuable, and careful observations continued for the next few years should yield reliable information of very great value in connection with the study of this disease, and possibly of others. Our records for the growing season of 1914 begin with April 23rd and are very nearly complete. The clock in the hygrothermograph was permitted to run down at the time when one rust infection was taking place; and two of the hygrothermograph records have been lost.

There was no rain from April 21st to April 25th. It began raining the morning of April 25th and continued intermittently all day. This was followed by very heavy showers in the evening and a steady rain which lasted until 9 A. M., April 26th. Sporidia were discharged in great numbers between 9 A. M. and 12 noon on Sunday, April 26th. The quadruple register records for this period of spore discharge show a variable wind having a general southeast to southwest direction; an average wind velocity of about four miles per hour; and continuous sunshine after 10 A. M. Sections from this chart are shown below:




Sections of quadruple register chart showing wind direction, wind velocity, rainfall, and sunshine from 8 A. M. April 26th, to 10:30 A. M. April 26th, 1914. A, indicates wind direction; B, wind velocity; C, rain until 9 A. M. and sunshine after 10 A. M.

The hygrothermograph record shows a rather rapid fall in humidity and an equally abrupt rise in temperature. The section of the chart for Saturday, April 25th and Sunday, April 26th is given:




Hygrothermograph record from Friday, April 24th to Monday, April 27th, 1914.

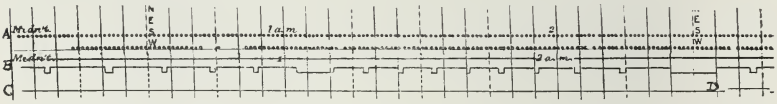
A general infection of apple foliage took place at this time, but it was not serious because there were only a few leaves unfolded. The blossom buds were just beginning to show color on April 26th and the central blossom did not open until May 1st. The leaves which enclose the blossom cluster were opened out sufficiently to receive infection and it was very noticeable on all of the trees sprayed May 4th that the leaves which came from a fruit bud were all quite heavily infected while those from a leaf bud did not show as much rust. Twigs covered with sacks on the afternoon of April 26th and uncovered on May 10th showed the extent of this infection.

It should be noted that a very light wind was sufficient to disperse the sporidia.

A shower occurred on the afternoon of April 29th, but did not have much effect on the cedar galls.

There was a shower about 5 P. M. on May 4th, and this was followed by a light rain from 6:30 P. M. to 11 P. M. The hygrothermograph record covering May 4th and 5th showed a drop of 10 to 15% in humidity between midnight and 2 A. M. May 5th. It began raining again at about 2:30 A. M. May 5th and continued until 10 A. M. of the same day.

Sections of the record from the quadruple register are given below:



Sections of quadruple register record from midnight May 4th to 2:45 A. M. May 5th, 1914. A, indicates wind direction; B, wind velocity; C, sunshine line; D, rainfall.

York Imperial twigs sacked immediately after it stopped raining on the morning of May 5th were just as badly diseased with rust as unprotected twigs on the same tree. Trees sprayed about 11 A. M. that day showed just as much rust as unsprayed trees. The sporidia discharge had occurred between 12 and 2:30 A. M. May 5th and the infection of apple foliage and fruit had evidently taken place at once. The wind which carried the sporidia was in a general southwest direction, varying to south and with a velocity of about ten miles per hour. Infection was general and quite severe.

There was no evidence of sporidia discharge during the forenoon of May 5th, although careful observations were made by exposing large watch glasses near the cedar galls for from one to six hours. The sporidia, if discharged in any numbers, would alight on the watch glass, and their presence could easily be detected with a microscope.

On May 8th it rained from about 8:30 A. M. until 12:30 P. M. and there were showers during the latter part of the afternoon and until 7:30 P. M. Sporidia were discharged during the night but there was no evidence of infection occurring at this time. The wind direction was extremely variable during the night of May 8th and 9th and its velocity was only 1½ to 2 miles per hour. It is probable that the sporidia dropped to the ground before they had been carried far from the sori which produced them.

There was another shower late in the afternoon on May 12th, but it was of short duration and no sporidia discharge

was noted. Light showers occurred on May 28th, 30th, and 31st, but no evidence of sporidia discharge or infection was noted as a result. The humidity ranged very low throughout the period from May 12th to June 4th and the temperature was comparatively high most of the time.

It rained during the forenoon of June 4th, and beginning again at about 4 P. M. that day, it rained intermittently all night. There was a slight, but rather general infection of apple rust at this time. The wind direction was south varying to southwest, but both wind velocity and humidity records covering this period happened to be incomplete.

The sori on the cedar rust galls were nearly exhausted by this date, and there was no further evidence of sporidia discharge or infection.

These observations and records have not been continued for a sufficient length of time to warrant drawing definite conclusions as to the exact relation of meteorological factors to sporidia discharge and infection. A few points which seem particularly worthy of mention are: (1) That, so far as our records go, there has been a drop in humidity every time that sporidia have been discharged; (2) That the sori appear particularly active after a prolonged dry spell, and seem to be temporarily exhausted by two or three closely successive sporidia discharges: (3) That there may be a very heavy discharge of sporidia without any general infection of apple foliage or fruit: (4) That an infection may take place during the night, under conditions which would have proven very deceptive and confusing without careful and exact records. Such an infection occurred the night of May 4th to 5th, 1914.

The development or stage of growth of the apple foliage is a very important factor in determining the amount of infection. Under West Virginia conditions many sporidia are likely to be disseminated before the leaves have unfolded sufficiently to receive infection. Careful field and laboratory experiments have shown that natural infection may take place on York Imperial leaves just as soon as they have unfolded enough to expose any portion of their upper surface,* although this does not agree with Fulton (1913, p. 64.) Inoculation experiments conducted in 1914 gave no infection on the lower

*From our experience, we are inclined to believe that the inoculation of very young leaves may be accomplished to better advantage by carrying the freshly discharged sporidia on to the leaf in an air current, rather than by using liquid suspensions.

## PLATE V.

Fig. 1—Rust galls of various sizes with expanded, gelatinous sori. Note small galls on single needles at right. (About natural size.)

Fig. 2—Larger rust galls with expanded, gelatinous sori. (About natural size.)

Fig. 3—Apples from trees with one side rust infection in 1912. The two at right were largest on side which showed least infection, while the two at left were largest on badly infected side. Collected about August 1, 1912.

leaf surface, as was reported by Coons (1912, p. 221). Sporidia in suspension were used for this work, and good infections were secured on upper leaf surfaces under the same conditions. Inoculation experiments early in the season of 1912 and repeated in 1913 gave severe infections of leaves which were just beginning to unfold. These inoculations, however, were made by gently rubbing the young leaves with gelatinous teliosori.

The gradual development of resistance, or immunity in the leaf is very striking and extremely important, and Reed (1914, p. 15) gives some records of it. There were two rust infections in 1911. We do not know the exact dates when they occurred, but one was probably just as the first blossoms were about to open and the other not until the latter part of May. The terminal growth on York Imperial twigs during that season commonly showed nine large leaves. The first three and last three leaves on such a growth were rust infected, while between them were three leaves free from rust. This was very noticeable, and was commented upon by many orchard men. The fourth, fifth and sixth leaves must have been immune at the time that the three youngest leaves were infected.

The same thing is clearly shown in Table XII. At the time when the important infection took place in 1913, the first three to five large leaves had become immune. Table XV indicates this in relation to the June 4th and 5th infection of 1914.

Stewart (1910, p. 317) says, "The spring of 1903 was very dry at Riverhead, Long Island. There was no precipitation

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of any importance between April 16th and June 8th. As a consequence, there was no opportunity for the infection of apple leaves until June 8th and 9th on which dates there were heavy showers and the cedar apples became swollen into yellow gelatinous masses of unusually large size. Very little rust occurred on the leaves that year." Evidently most of the leaves had become immune when that infection occurred.

During 1914, records were kept on several twigs showing the exact date when each leaf finally opened out from the bud. From the data for this season it would appear that a leaf was immune ten days after unfolding. The exact time required for a leaf to develop to the same extent during another season or under other conditions, might vary somewhat from this period.

The points to be emphasized are that the leaves do become immune, (due evidently to a thickening and hardening of the epidermal cells, as well as to other chemical and physical changes in the interior of the leaf), and that a rust infection of destructive proportions can hardly be expected to occur after June 1st, under West Virginia conditions.

A mature leaf may occasionally become infected through insect injuries Successful inoculations have also been made in mature leaves which were torn or injured by needle punctures. Infections of this kind develop very small spots, and aecia production has never been noted from them. They are not likely to be of economic interest.

The relative locations of orchards and cedar trees form an important factor in connection with rust epidemics. Obviously, a cedar tree has much better opportunity for effective dispersal of rust sporidia when it is located on ground higher than that of nearby apple orchards. These sporidia act much like grains of pollen or particles of dust when they are in the air. The distance to which they may be carried is largely dependent upon the wind, but the comparative elevation from which they start, and objects which may intercept them, must also be considered. McCarthy (1893, p. 86) states that mature spores may be carried for four miles in an unusually high wind. Thaxter, (1891, p. 3) says, "Although it has been shown that infection from cedars may take place at a distance of eight miles, the virulence of the disease is, of course, proportionate to the proximity of the cedars." It is

quite probable that freshly discharged sporidia are carried as far as eight miles in a high wind, but rarely, if ever, would other conditions be so favorable as to produce an infection of economic importance at that distance from the cedars.

## INFECTION OF CEDAR TREES.

The question has sometimes been raised as to how far an infection will be carried from the apple to the cedar. Before discussing this point, it should be stated that there appears to be very little known in regard to the exact manner of cedar tree infection, and the conditions which bring it about. The aeciospores, produced on apple foliage and fruit, are considerably larger than the sporidia, and presumably weigh more. Under the same conditions, we would not expect the aeciospores to be carried as far as the sporidia. Now, it would appear that, if the amount of rust infection in an apple orchard is appreciably reduced by cutting out the cedars for possibly one-fourth mile around it, the amount of infection which would be carried back to the cedars would be reduced in even greater proportion.

There are many reasons why this cannot be expected to work out in actual practice. The four reasons which we think to be most important are: 1. The presence of wild crab, seedling or neglected common apple trees near or among the cedars. 2. The presence of small orchards, and what might be termed door-yard apple trees in the close vicinity of the cedars. 3. The probability that the total period during which aeciospores are distributed is very many times greater than the total period of actual sporidia discharge. 4. The great variation in meteorological conditions. There are several important factors, such as wind and rain which would be considered under reason No. 4, and some others closely related to or associated with these factors, but it hardly seems best to enter into an extended discussion of these matters.

## PHYSIOLOGICAL EFFECT OF RUST ON APPLE TREES.

A question raised early in our work on this disease was as to the effect of rust on the general health of an apple tree. It was believed that the injurious effects of a serious rust infection would persist during the season following such an outbreak. There was very little evidence at hand in regard

## PLATE VI.

Fig. 1—Apple tree which suffered from one sided rust infection in 1912. Picture taken May 3, 1914. Note bloom on side which had least rust in 1912.

Fig. 2—Eleven year old York Imperial apple tree which has suffered from many severe rust infections.

Fig. 3—Eleven year old York Imperial apple tree which has not been a severe sufferer from rust infections.

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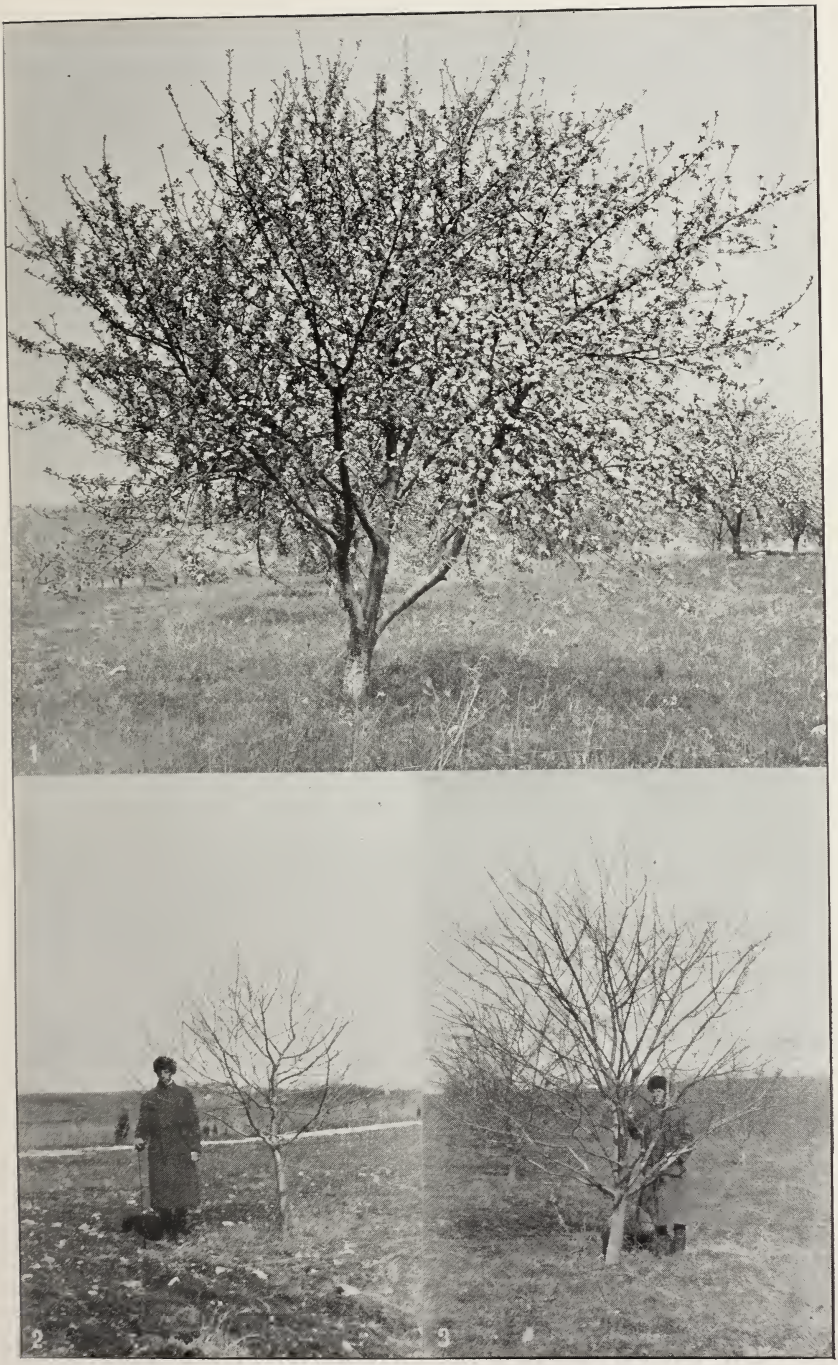
to this, and it appeared difficult to secure it since the infection is so general that all the trees of any one variety in a given section are likely to show nearly the same amount of disease.

Two orchards were finally found which may serve for some general comparisons. These orchards were less than two miles apart and will be designated as No. 1 and No. 2. The trees chosen for comparison were of the same variety, York Imperial, and the same age, 11 years. Orchard No. 1 had received good care, and happened to be so situated as not to have suffered from very severe infections of rust. One of the trees in this orchard is shown by Plate VI, fig. 3. This tree was growing under soil and drainage conditions as nearly comparable as possible with those of orchard No. 2. Orchard No. 2 had received what might be called fair cultural attention. It had been plowed, fertilized, and sprayed, but not quite so systematically and carefully as orchard No. 1. This orchard was not over ten or fifteen acres in area and there were cedar trees within two rods of it on every side. There were quite a number of large cedar trees, twenty to thirty feet high, within ten to twenty rods of the orchard, and many small cedars on all sides. In 1913, when particular note was first taken of this orchard, the cedar trees around it were practically loaded down with rust galls. A typical York Imperial tree in orchard No. 2 is shown by Plate VI, fig. 2. There were about equal numbers of York Imperial and of Ben Davis apple trees in the last mentioned orchard. The trees of both varieties were the same age and had received the same care, but the owner reports that the York Imperial trees have not borne more than an average of three



apples per tree while the Ben Davis trees have borne an average of three barrels per tree. The Ben Davis trees, right beside the York Imperials had made good growth. They were at least two-thirds larger than the York Imperial trees and appeared very healthy.

It seems safe to conclude that the lack of development of the York Imperial apple trees in orchard No. 2 was largely the effect of the serious rust infection recurring each year.

Another case which seems worthy of mention is that of some trees showing a far more severe infection on one side than on the other. This one-sided infection took place in 1912. The trees were York Imperial, about 12 years of age, in rows along the top of a ridge. There was a considerable number of cedars in the vicinity of the orchard, and a large grove of them a little way down on one slope of the ridge. A strong wind was blowing from this grove into the orchard at the time of infection, and the effects of the disease appeared to be at least twice as severe on the side toward the cedar grove as on the other side. On the side where infection was greatest, the apples were not more than two-thirds as large as those on the other side. (Plate V, fig. 3.)

In the spring of 1913 this orchard was visited and it was found that the trees which showed the one-sided rust infection in 1912 were not blooming at all on the side where the disease was so severe, while there was a very fair amount of bloom on the other side. No good photographs of the trees were secured at that time. A late spring frost destroyed all of the young fruit which had set on these trees, and it was believed that they would entirely recover to their normal condition by the following spring.

The orchard was visited again the spring of 1914, and evidences of the one-sided rust infection were still visible in the first four or five rows of apple trees extending along the top of the ridge. Quite a little individual variation in the trees could be noted, but there was a very clear difference between the two sides. The bloom was slight or scattering on the side where rust infection had been severe, and was very profuse on the other side. (Plate VI, fig. 1.)

The trees in question may have suffered from one-sided rust infections previous to 1912, but evidence from observation, or from the development of the trees, does not indicate

that such was a regular, or even frequent, occurrence. It should be noted that all cedars in the immediate vicinity of this orchard were destroyed during the winter of 1912-13 and that the radius of cedar-free territory was extended during the winter of 1913-14. Whatever rust infection took place in this orchard during the past two seasons was very uniformly distributed and can have had but little effect upon the one-sided fruit production of the trees in question.

Spraying experiments, conducted in 1912*, prevented serious rust infection on portions of certain York Imperial trees in one orchard. The only York Imperial bloom observed in this orchard in 1913 was on the parts of trees where rust had been controlled the previous season. It was also observed in 1913 that these portions of trees retained their foliage longer than unsprayed portions of the same tree and longer than any unsprayed trees in the orchard. Their condition was not noted in 1914.

Spraying experiments were again conducted in 1913 but practically all of the young fruits were destroyed by late frosts and general rust infection was not so severe as in 1912. The number of leaves showing rust spots and the number not so diseased were determined on one or more twigs of each tree used in these experiments. This count was made about June 10th and the two small leaves, which unfolded first, were removed before counting. The leaves were again counted during the first week in October, and from this count it was possible to determine the number of rusted leaves which had fallen as compared with the number of rust-free ones which had fallen. The results are briefly summarized in the following table:

Table I.—*Leaf fall as affected by rust in 1913.*

| | No. leaves in June | No. leaves in October | No. leaves fallen | Percent fallen |
|---|---|---|---|---|
| Rusted | 657 | 135 | 522 | 79.4 |
| Rust-free | 943 | 522 | 421 | 44.6 |
| Total | 1600 | 657 | 943 | 58.9 |

This table includes counts from ten trees chosen at random from among those upon which rust had not been controlled. Detailed tables might be given, but they would show little more, and the data for 1914 will be of more interest and

*The 1912 experiments were conducted in an orchard owned by D. Gold Miller at Gerrardstown. The 1913 experiments were conducted in the orchards of Hon. George M. Bowers, and B. Frank Mish at Inwood. The 1914 experiments were conducted in the orchard of Dr. A. P. Thompson at Summit Point. Acknowledgement is due these gentlemen for their courtesy to us in connection with this work.

## PLATE VII.

Fig. 1—York Imperial apple tree upon which rust was controlled by spraying in 1913.

Fig. 2—York Imperial apple tree upon which rust was not controlled in 1913. This tree is just adjacent to the one shown in fig. 1.

value along this line. The effect of rust control upon leaf fall in 1913 is indicated by Plate VII, figs. 1 and 2.

During the season of 1914 this phase of the work was enlarged to include the location of each leaf in regard to order of opening from bud, and the number of rust spots on each leaf as well as the number of leaves. The two small, oldest leaves were removed before counts were made. These detailed field counts were made on twenty-five trees, and included about 320 leaf clusters, of which one-half were terminal growths of twigs. Ten of the trees were unsprayed, five had been sprayed with lime-sulphur, five with Bordeaux mixture, and five with atomic sulphur. The rust was quite well controlled on the sprayed trees.

A sample page of the records on these leaves is shown:

Tree No. 323. Twig No. 2—Check. (See footnote *)

Treatment—Lime-sulphur—Block F.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Terminal Growth | No. of leaf†.... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | Rust spots..... | 9 | 22 | 9 | 4 | 0 | 0 | 0 | 0 | 8 |
| | Date fallen..... | 7-30 | 7-30 | 10-3 | 10-30 | | 10-30 | | | 10-3 |
| Side Spur No. 10 | Rust spots..... | 8 | 17 | 16 | 0 | 0 | 0 | | | |
| | Date fallen.... | 10-3 | 7-30 | 10-3 | 7-30 | | | | | |

*This was a *check* twig on a *sprayed* tree.
†Leaf No. 1 is the oldest.

The data from these records has been carefully tabulated and is given in condensed form as Table II. This table is arranged to show the number of leaves having one rust spot,

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the number having two rust spots, etc. It also gives the number of such leaves which had fallen between specified dates. For example, there were 137 leaves having two rust spots each. Six of these leaves fell between July 6th and August 1st; four between August 1st and September 1st; 22 between September 1st and October 1st; and 30 between October 1st and November 1st. There were 62 of these leaves which dropped between July 6th and November 1st, 1914, and 75 leaves, each showing two rust spots, still remained upon the twigs. The first counts were made July 3rd to 9th, and some of the badly rusted leaves had already fallen at that time. Counts were again made July 28-30, August 27-30, October 2-5 and October 30-31.

Table II.—*Leaf fall as influenced by the number of rust spots per leaf.*

| Number spots on each leaf | Number of leaves | Number of leaves fallen by periods | | | | Total number of leaves fallen | Number of leaves on twig Nov. 1. |
|---|---|---|---|---|---|---|---|
| | | July 6 to Aug. 1 | Aug. 1 to Sept. 1 | Sept. 1 to Oct. 1 | Oct. 1 to Nov. 1 | | |
| 0 | 832 | 23 | 9 | 45 | 122 | 199 | 633 |
| 1 | 266 | 6 | 6 | 39 | 65 | 116 | 150 |
| 2 | 137 | 6 | 4 | 22 | 30 | 62 | 75 |
| 3 | 75 | 5 | 2 | 13 | 12 | 32 | 43 |
| 4 | 82 | 6 | 0 | 16 | 20 | 42 | 04 |
| 5 | 56 | 2 | 6 | 14 | 10 | 32 | 24 |
| 6 | 60 | 7 | 3 | 16 | 13 | 39 | 21 |
| 7 | 47 | 7 | 3 | 12 | 8 | 30 | 17 |
| 8 | 39 | 4 | 3 | 12 | 9 | 28 | 11 |
| 9 | 29 | 3 | 1 | 12 | 3 | 19 | 10 |
| 10 | 28 | 2 | 3 | 10 | 4 | 19 | 9 |
| 11 | 21 | 4 | 3 | 5 | 5 | 17 | 4 |
| 12 | 25 | 5 | 6 | 9 | 3 | 23 | 2 |
| 13 | 26 | 2 | 1 | 15 | 3 | 21 | 5 |
| 14 | 26 | 7 | 4 | 11 | 2 | 24 | 2 |
| 15 | 27 | 3 | 5 | 10 | 6 | 24 | 3 |
| 16 | 23 | 7 | 2 | 8 | 3 | 20 | 3 |
| 17 | 25 | 7 | 5 | 7 | 3 | 22 | 3 |
| 18 | 21 | 5 | 5 | 4 | 6 | 20 | 1 |
| 19 | 17 | 3 | 2 | 11 | 0 | 16 | 1 |
| 20 | 16 | 2 | 2 | 9 | 2 | 15 | 1 |
| 21 | 23 | 9 | 6 | 5 | 3 | 23 | 0 |
| 22 | 18 | 6 | 2 | 7 | 1 | 16 | 2 |
| 23 | 13 | 3 | 1 | 6 | 3 | 13 | 0 |
| 24 | 23 | 12 | 5 | 4 | 2 | 23 | 0 |
| 26 | 29 | 12 | 8 | 8 | 1 | 29 | 0 |
| 28 | 29 | 11 | 11 | 7 | 0 | 29 | 0 |
| 30 | 28 | 11 | 10 | 3 | 4 | 28 | 0 |
| 33 | 33 | 10 | 11 | 12 | 0 | 33 | 0 |
| 36 | 26 | 5 | 15 | 4 | 2 | 26 | 0 |
| 40 | 29 | 8 | 13 | 6 | 2 | 29 | 0 |
| 45 | 28 | 9 | 13 | 6 | 0 | 28 | 0 |
| 50 | 13 | 8 | 4 | 1 | 0 | 13 | 0 |
| 55 | 17 | 7 | 7 | 2 | 1 | 17 | 0 |
| 60 | 10 | 7 | 2 | 1 | 0 | 10 | 0 |
| over 60 | 23 | 13 | 7 | 2 | 1 | 23 | 0 |
| Totals ..... | 2220 | 247 | 190 | 374 | 349 | 1160 | 1060 |

It should be possible from this table to get an indication as to how quickly and how seriously a York Imperial apple tree is likely to be defoliated by a certain amount of rust infection on the leaves. In order to bring out this point, we have further condensed Table II by dividing the leaves into five groups, those having no rust spots, those having one to four rust spots, those having five to nine rust spots, those having ten to fourteen rust spots. The results thus secured are shown below:

Table III.—*Leaf fall as influenced by number of rust spots per leaf.*

| Number of rust spots per leaf | Number of leaves | Number of leaves fallen by periods | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | July 6 to Aug. 1 | | Aug. 1 to Sept. 1 | | Sept. 1 to Oct. 1 | | Oct. 1 to Nov. 1 | |
| | | No. | Percent | No. | Percent | No. | Percent | No. | Percent |
| None | 832 | 23 | 3.8 | 9 | 1.1 | 45 | 5.5 | 122 | 14.8 |
| 1 to 4 inc. | 560 | 23 | 4.1 | 12 | 2.1 | 90 | 16.1 | 127 | 22.7 |
| 5 to 9 inc. | 231 | 23 | 10. | 16 | 6.9 | 66 | 28.5 | 43 | 18.6 |
| 10 to 14 inc. | 126 | 20 | 15.9 | 17 | 13.5 | 50 | 39.7 | 17 | 13.5 |
| 15 or more | 471 | 158 | 33.5 | 136 | 28.9 | 123 | 26.2 | 40 | 8.5 |

| Number of rust spots per leaf | Number of leaves | Total fallen July 6 to Nov. 1 | | Left on tree Nov. 1 | |
|---|---|---|---|---|---|
| | | No. | Percent | No. | Percent |
| None | 831 | 199 | 24.2 | 633 | 75.8 |
| 1 to 4 inc. | 560 | 252 | 45. | 308 | 55. |
| 5 to 9 inc. | 231 | 148 | 64. | 83 | 36. |
| 10 to 14 inc. | 126 | 104 | 82.6 | 22 | 17.4 |
| 15 or more | 471 | 457 | 97.1 | 14 | 2.9 |

Normal leaf fall was beginning to increase by the latter part of October, so that the more important results are to be found between the dates of July 6th and October 4th, or October 1st as given in Table II. It may be readily determined that the number of leaves fallen on October 1st is closely proportional to the number of spots per leaf. This applies particularly to leaves having from one to nine spots, where the original numbers of such leaves were large enough to be fairly compared.

Additional tables might be given to show the results from sprayed and unsprayed trees, but they would indicate little that is not already shown in Table II. The sprayed trees, of course, have fewer rusted leaves, and comparatively more leaves with a small number of spots per leaf, but **the percent-**

age of leaf fall appears to be fairly constant for leaves showing a certain number of rust spots.

One other condensed table may well be included to show the effect of rust on foliage retention during the season of 1914. This table, No. IV, includes records from 58 trees and about 300 twigs. The data already given for 1914 is included.

Table IV.—*Leaf fall as affected by rust in 1914.*

| | | | | |
|---|---|---|---|---|
| No. trees included | 18 | 18 | 23 | 9 |
| Treatment | atomic sulphur | Bordeaux | lime-sulphur | check |
| No. leaves counted | 4553 | 4257 | 5493 | 2030 |
| Percent of leaves rusted | 63. | 32.3 | 31.2 | 86.7 |
| No of spots per rusted leaf | 4.8 | 2.5 | 2.9 | 17.5 |
| Percent leaves fallen before Oct. 4 | 35.9 | 26.7 | 22.6 | 72.6 |

It should be noted that this table shows the **total leaf fall** between July 6th and **October 4th.**

Turning now to the fruit we would refer first to Plate V and Plate VIII as indicating in a general way the fact that a severe rust infection greatly reduces the size of the fruit. In October 1914, twenty-eight trees were carefully selected from which to secure data. The apples were sorted as to grades, firsts being about 2½" or over, and seconds about 2" to 2½"; and as to the number of rusted and non-rusted fruits in each grade. Tables V to VIII give the detailed results, according to the treatment. The dropped fruits mentioned in these tables are such as were under the tree at picking time.

Table V.—*Number and grade of fruit from eight check trees.*

| | Bushels | Number | Percent | Rusted | | Healthy | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Number | Percent | Number | Percent | |
| Picked Fruits | | | | | | | | Total Firsts 3728 20.0% |
| Firsts | 14¾ | 2612 | 25.0 | 1897 | 72.7 | 715 | 27.3 | |
| Seconds | 15¾ | 3754 | 36.0 | 2813 | 74.7 | 941 | 25.3 | |
| Culls | 11 | 4020 | 39.0 | 3050 | 75.9 | 970 | 24.1 | Total Seconds 6059 32.5% |
| Total picked | 41½ | 10386 | | 7760 | 74.9 | 2626 | 25.1 | |
| Dropped Fruits | | | | | | | | |
| Firsts | | 1116 | 13.7 | 730 | 65.5 | 386 | 34.5 | |
| Seconds | | 2305 | 28.0 | 1538 | 66.8 | 767 | 33.3 | |
| Culls | | 4815 | 58.3 | 3407 | 70.8 | 1408 | 29.2 | Total Culls 8835 47.5% |
| Total drops | | 8236 | | 5675 | 68.8 | 2561 | 31.2 | |
| Grand total | | 18622 | | 13435 | 72.2 | 5187 | 27.8 | Drops, 44.1% |

Average number of apples per tree, 2328.

Table VI.—*Number and grade of fruit from six trees sprayed with lime-sulphur.*

| | Bushels | Number | Percent | Rusted | | Healthy | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Number | Percent | Number | Percent | |
| Picked Fruits | | | | | | | | Total Firsts 6676 45.3% |
| Firsts | 35 | 4904 | 57.5 | 1699 | 34.5 | 3205 | 65.5 | |
| Seconds | 7 | 1652 | 19.4 | 672 | 40.7 | 980 | 59.3 | |
| Culls | 5 | 1944 | 23.2 | 809 | 41.6 | 1135 | 58.4 | |
| Total picked | 47 | 8500 | | 3180 | 37.4 | 5320 | 62.6 | Total Seconds 3396 23.1% |
| Dropped Fruits | | | | | | | | |
| Firsts | | 1772 | 28.5 | 632 | 35.7 | 1140 | 64.3 | |
| Seconds | | 1744 | 28.0 | 704 | 40.4 | 1040 | 59.6 | |
| Culls | | 2712 | 43.5 | 1086 | 40.0 | 1626 | 60.0 | Total Culls 4656 31.6% |
| Total drops | | 6228 | | 2422 | 38.9 | 3806 | 61.1 | |
| Grand total | | 14728 | | 5602 | 38.1 | 9126 | 61.9 | Drops, 42.4% |

Average number of apples per tree, 2455.

Table VII.—*Number and grade of fruit from eight trees sprayed with Bordeaux mixture.*

| | Bushels | Number | Percent | Rusted | | Healthy | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Number | Percent | Number | Percent | |
| Picked Fruits | | | | | | | | Total Firsts 8435 38.5% |
| Firsts | 39¼ | 6323 | 44.0 | 3044 | 48.1 | 3279 | 51.9 | |
| Seconds | 17¾ | 4277 | 29.7 | 2201 | 51.5 | 2076 | 48.5 | |
| Culls | 10¼ | 3805 | 26.3 | 1924 | 50.7 | 1881 | 49.3 | Total Seconds 6795 30.9% |
| Total picked | 67¼ | 14405 | | 7169 | 49.6 | 7236 | 50.4 | |
| Dropped Fruits | | | | | | | | |
| Firsts | | 2112 | 27.9 | 1065 | 50.3 | 1047 | 49.7 | |
| Seconds | | 2518 | 33.4 | 1252 | 49.5 | 1266 | 50.5 | |
| Culls | | 2921 | 38.7 | 1484 | 50.8 | 1437 | 49.2 | Total Culls 6726 30.6% |
| Total drops | | 7551 | | 3801 | 50.3 | 3750 | 49.7 | |
| Grand total | | 21956 | | 10970 | 50.0 | 10986 | 50.0 | Drops, 34.5% |

Average number of apples per tree, 2744.

Table VIII.—*Number and grade of fruit from six trees sprayed with atomic sulphur.*

| | Bushels | Number | Percent | Rusted | | Healthy | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Number | Percent | Number | Percent | |
| Picked Fruits | | | | | | | | Total Firsts 5589 32.7% |
| Firsts | 27¾ | 4401 | 37.6 | 2114 | 47.9 | 2287 | 52.1 | |
| Seconds | 17 | 3652 | 31.2 | 2049 | 56.0 | 1603 | 44.0 | |
| Culls | 10 | 3657 | 31.2 | 1952 | 53.3 | 1705 | 46.7 | |
| Total picked | 54¾ | 11710 | | 6115 | 52.2 | 5595 | 47.8 | Total Seconds 5604 32.8% |
| Dropped Fruits | | | | | | | | |
| Firsts | | 1188 | 22.1 | 583 | 49.0 | 605 | 51.0 | |
| Seconds | | 1952 | 36.2 | 1001 | 51.3 | 951 | 48.7 | |
| Culls | | 2246 | 41.7 | 1263 | 56.3 | 983 | 43.7 | Total Culls 5903 34.5% |
| Total drops | | 5386 | | 2847 | 52.8 | 2539 | 47.2 | |
| Grand total | | 17096 | | 8962 | 52.4 | 8134 | 47.6 | Drops, 31.5% |

Average number of apples per tree, 2849.

It will be noted that there does not appear to be any greater number of rusted fruits among the drops than among those picked. Evidently the rust infected fruit does not show any greater tendency to drop than the other fruit during the latter part of the season. It would be interesting to know whether or not the proportion is the same for rusted fruit drops of the early season, but our records do not cover this point.

The differences in grade of fruit for the various treatments are quite apparent. It must be remembered, however, when we consider this point that the amount of leaf infection may be a prominent factor in the size of fruit. We believe that leaf infection is a far more important factor than fruit infection in determining fruit size.

The fruit data is given in condensed form below:

Table IX.—*Summary of rust effect on fruit.*

| | Treatment | | | |
|---|---|---|---|---|
| | Atomic sulphur | Bordeaux | Lime-sulphur | Check |
| No. fruits counted | 17096 | 21956 | 14728 | 18622 |
| Percent fruits rusted | 52.4 | 50.0 | 42.4 | 72.2 |
| Percent picked firsts | 32.7 | 38.5 | 45.3 | 20.0 |
| Percent picked seconds | 32.8 | 30.9 | 23.1 | 32.5 |
| Percent picked culls | 34.5 | 30.6 | 31.6 | 47.5 |
| No. of trees | 6 | 8 | 6 | 8 |
| Average number of fruits per tree | 2849 | 2744 | 2455 | 2328 |

Some of the evident physiological effects of apple rust infections are premature loss of foliage, under-development of fruit, and in severe cases a great loss of vitality on the part of the tree as indicated by small size, failure to develop fruit buds, etc.

## PHYSIOLOGICAL EFFECT OF RUST ON THE CEDAR TREE.

Some of the effects of this fungus upon the cedar tree, *Juniperus virginiana*, have been observed in connection with our work on apple rust, and it may not be out of place to briefly mention them at this time. The production of cedar rust galls of varying size and form is too well known to need further mention. (Plate III, fig. 5.)

A cedar tree which is very heavily infected with rust gives evidence of injury by less vigorous growth. This is especially apparent if the tree has been thus infected on two or more successive years. In particularly severe cases the death of portions of a cedar tree may result.

The apparent immunity of certain cedar trees has been frequently commented upon, and various theories have been advanced to account for this condition. In sections where the rust is destructive, it is quite common to see cedar trees with few or no galls, while other trees within a few feet are actually loaded down with them. Close observation of these "immune" cedar trees has led up to believe that such immunity as they may possess is often a direct result of previous heavy infections. Infection by *Gymnosporangium Juniperi-virginianae* apparently takes place only in young growth. If the tree has been severely diseased with this rust for two or more successive seasons its growth is greatly inhibited, and the opportunity for infection would be proportionately reduced. The two-year life cycle of the fungus must be borne in mind when considering this possibility, as an infection taking place in 1913 does not become apparent until 1914.

A noticeable variation in rate and period of growth has also been observed among cedar trees which were some distance from any apple orchards. It may be that growth factors other than those resulting from rust infection have some bearing upon this matter. We do not have any exact records to prove or disprove this theory, but it is a matter worthy of careful attention.

## PLATE VIII.

Fig. 1—Eighteen typical apples from sprayed portion of York Imperial tree, treated May 6, at left. Same number of typical fruits from an unsprayed York Imperial tree, at right. Experiments conducted in 1912.

Fig. 2—Marketable fruit from sprayed portion of York Imperial tree, sprayed May 6, at left. Total fruit from controlled portion of same tree, at right. Experiments conducted in 1912.

Fig. 3—A row of roadside cedars and an apple tree in bloom. Note apple tree is situated in row along with cedars.

Professor H. H. Whetzell of Cornell University advises us that he has observed a specific case of this apparent immunity in cedars. He has kindly granted up permission to use the following statement.*

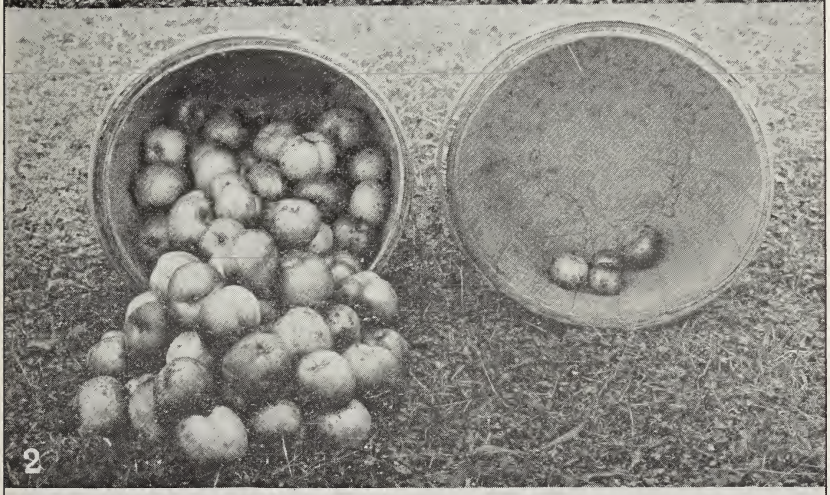
"During my senior year in Wabash College I made some studies of the *Gymnosporangium macropus* which occurs very abundantly on cedars and apple trees about Crawfordsville, Indiana. I observed that certain cedar trees were very badly infected, being loaded with galls, large and small, on all their twigs and branches. Other trees standing near were almost or quite free from any infection. A couple of years later I returned to Crawfordsville for a visit and went out again to see the cedar trees from which I had, during my senior year, gotten such large quantities of galls. To my astonishment they were practically free from infection, while others nearby that had borne no galls before were now badly covered with them. What the explanation of this phenomenon is I do not know. It occurred to me, however, that a serious infection of the trees one season might have rendered them more or less immune for a time That the infection was on different trees in these two years is certain, as I was very familiar with the different trees with which I had worked."

## CONTROL OF RUST BY SPRAYING.

Ever since spraying for orchard diseases became widely adopted there have been occasional attempts to control apple rust by this method. The varying successes of these trials have been mentioned under historical notes.

*This statement is from unpublished records made by Prof. Whetzell, in connection with some of his early work.

1



2

3

The incidents directly responsible for our taking up experiments along this line were a very severe outbreak of the rust in the eastern part of the state in 1910, and a case in which a few trees were kept free from it by means of spraying. These controlled trees were part of a row along one side of a large orchard. The owner had some atomic sulphur on hand and, incidentally applied it to these apple trees to see how effective it would be. It was at once assumed by nearly everyone in that section that this spray would control rust, while others would not. Inquiry failed to locate any other apple trees sprayed on the same date, and a belief was expressed that lime-sulphur, or Bordeaux mixture, would control this disease just as effectively as the atomic sulphur, if it were applied at the right time.

During the season of 1911 the rust was not very severe, but no orchards were seen in which spraying had effectively controlled it.

**Field Experiments in 1912.** In 1912 experiments were undertaken to determine the possibility and the practicability of controlling apple rust by the use of spray materials. The orchard selected for this work consisted of about 300 York Imperial trees and 300 of Ben Davis and other varieties combined. It was situated about two miles northwest of Inwood and was commonly known as the Tabb orchard. The cedar trees had been largely cleared away on two sides of the orchard, but were fairly numerous in pasture land bordering the other sides. A nearly square block consisting of 19 York Imperial and 19 Ben Davis trees was chosen near one end of the orchard. The trees were so located that one might reasonably expect them to receive uniform infection.

The only sprays applied to them during the season were those used in this work.

The materials tried were Bordeaux mixture (3 lbs. copper sulphate, 5 lbs. lime, 50 gallons water), commercial lime-sulphur (1 gal. to 40 gals. of water) and atomic sulphur (7 lbs. to 50 gals. of water). Each tree was divided into four parts by imaginary vertical planes. A two-cylinder hand pump was used in applying the spray and a pressure of 50 to 75 lbs. was maintained. One portion of the tree was left unsprayed and each of the other portions was treated with one of the above three spray materials. A large rubber blanket was spread over as much of the control portion as it

would cover, while the tree was being sprayed. A large tag was placed on a branch near the center of each of the four portions after spraying, and no tree was sprayed on more than one date.

Two trees, one Ben Davis and one York Imperial, were handled in this manner on April 22, 24, 29, May 4, 6, 8, 10, 13, 15, 18, 20, 22, 27 and 29. Other trees were similarly treated, but using only Bordeaux and lime-sulphur, on April 18, 20 and May 1: while still others received only lime-sulphur and atomic sulphur on April 26 and May 2.

Before the last of May it became evident that the disease was very largely controlled on certain trees. The sprayed portions of the trees treated May 4 and May 6 were especially free from rust. Counts were made early in June to determine the number of diseased and the number of healthy leaves resulting from each treatment. The results secured from trees sprayed April 26 to May 10 are given below:

Table X.—*Rust control on apple foliage in 1912.*

| | York Imperial | | | | Ben Davis | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Bord. mixt. | Lime-sul. | Atomic sul. | Control | Bord. mix. | Lime-sul. | Atomic sul. |
| April 26 | | | | | | | | |
| No. leaves counted | 17 | ..... | 50 | 52 | 43 | ..... | 29 | 35 |
| Percent diseased | 60.0 | ..... | 66.0 | 70.0 | 34.8 | ..... | 34.4 | 42.8 |
| April 29 | | | | | | | | |
| No. leaves counted | 163 | 151 | 137 | 134 | 106 | 137 | 133 | 121 |
| Percent diseased | 58.9 | 43.7 | 46 | 64.1 | 38.8 | 18.9 | 30.8 | 33.0 |
| May 1 | | | | | | | | |
| No. leaves counted | 125 | 140 | 139 | ..... | 135 | 139 | 141 | ..... |
| Percent diseased | 80.6 | 65.7 | 51.1 | ..... | 50.3 | 20.0 | 27.6 | ..... |
| May 2 | | | | | | | | |
| No. leaves counted | 135 | ..... | 160 | 110 | 136 | ..... | 149 | 128 |
| Percent diseased | 70.4 | ..... | 60.6 | 50.0 | 47.1 | ..... | 20.8 | 22.6 |
| May 4 | | | | | | | | |
| No. leaves counted | 145 | 156 | 147 | 147 | 130 | 185 | 121 | 158 |
| Percent diseased | 86.9 | 23.7 | 53.0 | 35.4 | 37.7 | 8.1 | 16.5 | 19.6 |
| May 6 | | | | | | | | |
| No. leaves counted | 126 | 150 | 151 | 143 | 157 | 181 | 121 | 146 |
| Percent diseased | 78.6 | 22.6 | 23.8 | 23.7 | 34.3 | 3.9 | 10.7 | 23.9 |
| May 8 | | | | | | | | |
| No. leaves counted | 138 | 160 | 145 | 154 | 175 | 127 | 142 | 138 |
| Percent diseased | 63.7 | 63.1 | 75.8 | 42.9 | 39.4 | 29.9 | 37.3 | 32.6 |
| May 10 | | | | | | | | |
| No. leaves counted | 55 | 56 | 25 | 35 | 39 | 30 | 33 | 49 |
| Percent diseased | 82.0 | 71.4 | 84.0 | 80.0 | 38.5 | 26.6 | 42.4 | 51.1 |

It will be seen from this table that each of the three spray materials applied May 6th was quite effective in controlling the rust. Trees sprayed May 4th were fairly well protected, while those sprayed May 2nd showed no benefit.

Notes as to the number of rust spots per leaf show that they were greatly reduced on the sprayed portions of the trees treated May 4th and 6th, but actual counts of them were not made.

The only marketable York Imperial apples in this orchard were secured from the tree sprayed May 6th. Unfortunately, there was little fruit on either the Bordeaux or control portion of this tree.

It was generally stated among the orchard men that the York Imperial fruit was not apt to be attacked to a very great extent. Counts of 600 apples taken from several unsprayed York Imperial trees showed an average of 85% of the fruit rusted, while there were practically no rusted fruits on the sprayed portions of the tree treated May 6th. A comparatively small number of these fruits were deformed by the disease and this was what had evidently led to the belief that only a small number were infected.

The results secured for this season would indicate that there was a very limited period of time when spraying for control of rust might be successfully undertaken. It should also be noted that the trees were in bloom from about May 2nd to May 5th of this year. Beach (1900) found that spraying in bloom caused a very pronounced decrease in the amount of fruit set. The same thing may have been true of the trees used in these experiments, but they all carried a heavy crop of fruit.

**Field Experiments in 1913.** The Frank Mish orchard and George M. Bowers' orchard at Inwood were selected for this work. The Mish orchard consisted of about 100 York Imperial, 100 Ben Davis and 200 pear trees, while the Bowers orchard contained about 225 York Imperial trees. The trees in the Mish orchard were 11 years old while those in the Bowers orchard were 12 to 14 years old. A great many cedars had been cut in the vicinity of these orchards, but enough remained to give a very heavy rust infection under favorable conditions.

The spray outfit used was Gould's Monarch hand pump mounted in a light wagon. The materials tested were 32° B. lime-sulphur, (1 to 40); Bordeaux mixture, (3 lbs. copper sulphate and 5 lbs lime to 50 gals. water); and atomic sulphur, (7 lbs. to 50 gals. water).

The schedule of spray applications made in these two orchards is given below:

Table XI.—*Spraying dates in 1913 experiments.*

BOWERS ORCHARD.

| Date | 4-16 | 4-17 | 4-18 | 4-22 | 4-23 | 4-24 | 4-25 | 4-26 | 4-28 | 4-29 | 4-30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-sulphur | x | x | x | x | x | x | x | x | x | x | x |
| Atomic sulphur | x | x | x | x | x | x | x | x | x | x | x |
| Bordeaux | x | x | x | x | x | x | x | x | x | x | x |

| Date | 5-1 | 5-2 | 5-3 | 5-5 | 5-6 | 5-8 | 5-12 | 5-15 | 5-19 | 5-22 | 5-26 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-sulphur | x | x | x | x | x | x | x | x | x | x | x |
| Atomic sulphur | x | x | x | x | x | x | x | x | x | x | x |
| Bordeaux | x | x | x | x | x | x | x | x | x | x | x |

MISH ORCHARD

| Date | 4-16 | 4-17 | 4-18 | 4-21 | 4-22 | 4-23 | 4-24 | 4-25 | 4-29 | 4-30 | 5-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-sulphur | x | x | x | x | x | | x | x | x | x | x |
| Atomic sulphur | x | x | x | | | x | x | x | | x | x |
| Bordeaux | x | x | x | x | | x | x | x | x | x | x |

| Date | 5-2 | 5-3 | 5-5 | 5-8 | 5-14 |
|---|---|---|---|---|---|
| Lime-sulphur | x | x | x | x | x |
| Atomic sulphur | | x | x | x | x |
| Bordeaux | | x | x | | x |

Three trees were included in the test for each material, on every date, in the Bowers orchard; and two trees (one York Imperial and one Ben Davis) for each material on every date in the Mish orchard. There was a fair amount of bloom in the Bowers orchard and scattering bloom on the Yorks in the Mish orchard. The Ben Davis trees in the latter orchard had very fair bloom, but late frosts destroyed practically all of the fruit in both orchards. In Table XII is given the number and distribution of rust spots on foliage in the Bowers orchards.* The twigs used in making these counts were carefully selected to show average conditions and were taken from different sides of the trees.

*In some cases it will be noted that there are over 300 rust spots per leaf. The spot counts up to 200 per leaf are believed to be very accurate, but there is probably an error of 5% in any count which runs above 300 spots per leaf.

Table XII.—*Number and distribution of rust spots on York Imperial apple foliage in Bowers orchard during 1913.*

| | Tree Number, 176<br>Treatment, Lime-sulphur<br>Date of Treatment, May 15, 1913 | | | | | | | | | | | | Tree Number, Check<br>Treatment, None | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spur number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| No. of leaves | 13 | 12 | 9 | 6 | 7 | 8 | 10 | 7 | 7 | 7 | 7 | 5 | 8 | 11 | 5 | 11 | 13 | 5 | 8 | 7 | 9 | 10 | 5 | 9 |
| No. of rust spots | 15 | 3 | 12 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 296 | 792 | 139 | 511 | 886 | 478 | 345 | 603 | 347 | 471 | 371 | 373 |
| Distribution of rust spots — Leaf No. 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Leaf No. 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| Leaf No. 3 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 7 | 0 | 0 | 30 | 0 |
| Leaf No. 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 | 0 | 1 | 124 | 1 | 171 | 0 | 0 | 206 | 0 |
| Leaf No. 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 97 | 0 | 0 | 334 | 26 | 303 | 1 | 0 | 134 | 0 |
| Leaf No. 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 13 | 4 | | 46 | 0 | | 207 | 121 | 64 | 0 | | 2 |
| Leaf No. 7 | 0 | 0 | 0 | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | | 155 | 48 | | 86 | 72 | | 103 | 0 | 215 | 0 | | 16 |
| Leaf No. 8 | 0 | 0 | 6 | | | 0 | 0 | | | | | | 127 | 333 | | 297 | 229 | | 8 | | 67 | 25 | | 252 |
| Leaf No. 9 | 0 | 0 | 0 | | | | 0 | | | | | | | 331 | | 69 | 357 | | | | 0 | 276 | | 103 |
| Leaf No. 10 | 5 | 0 | | | | | 0 | | | | | | | 76 | | 13 | 207 | | | | | 170 | | |
| Leaf No. 11 | 7 | 0 | | | | | | | | | | | | 0 | | 0 | 20 | | | | | | | |
| Leaf No. 12 | 0 | 0 | | | | | | | | | | | | | | | 0 | | | | | | | |
| Leaf No. 13 | 0 | | | | | | | | | | | | | | | | 0 | | | | | | | |

| | |
|---|---|
| Total number leaves | 98 |
| Total rusted leaves | 16 |
| Percent rusted leaves | 16.3 |
| Total rust spots | 35 |
| Spots per rusted leaf | 2.2 |

| | |
|---|---|
| Total number leaves | 101 |
| Total rusted leaves | 50 |
| Percent rusted leaves | 50.0 |
| Total rust spots | 5312 |
| Spots per rusted leaf | 112 |

The general effectiveness of these sprays for controlling the rust in the Bowers orchard is shown in Table XIII. The rust infection was very unevenly distributed through this orchard as a result of there being some large cedars within two or three rods of it, along one side. The first check tree given in this table was quite near some of these cedars.

Table XIII.—*Rust control on York Imperial apple foliage in Bowers orchard during 1913.*

| No. | Date | Treatment | Total | Rusted | | Healthy | | Spots per rusted leaf |
|---|---|---|---|---|---|---|---|---|
| | | | | Number | Percent | Number | Percent | |
| 128 | 5-3 | Lime-sulphur .... | 100 | 42 | 42.0 | 58 | 58.0 | 80.5 |
| 132 | 5-3 | Bordeaux ..... | 75 | 29 | 38.7 | 46 | 61.3 | 32.7 |
| 129 | 5-3 | Atomic sulphur.... | 100 | 30 | 30.0 | 70 | 70.0 | 32.3 |
| 161 | 5-8 | Lime-sulphur .... | 87 | 15 | 17.3 | 72 | 82.7 | 13.1 |
| 163 | 5-8 | Bordeaux ..... | 100 | 30 | 30.0 | 70 | 70.0 | 9.9 |
| 156 | 5-8 | Atomic sulphur.... | 98 | 29 | 29.5 | 69 | 70.5 | 16.8 |
| 168 | 5-12 | Lime-sulphur .... | 91 | 12 | 13.2 | 79 | 86.8 | 5.3 |
| 167 | 5-12 | Bordeaux ..... | 111 | 28 | 25.2 | 83 | 74.9 | 20.3 |
| 171 | 5-12 | Atomic sulphur.... | 109 | 21 | 19.3 | 88 | 80.7 | 9.1 |
| 176 | 5-15 | Lime-sulphur .... | 98 | 16 | 16.3 | 82 | 83.7 | 2.2 |
| 181 | 5-15 | Bordeaux ..... | 116 | 28 | 24.1 | 88 | 75.9 | 2.9 |
| 178 | 5-15 | Atomic sulphur.... | 112 | 24 | 21.4 | 88 | 78.6 | 10.1 |
| | | Check ..... | 101 | 49 | 48.6 | 52 | 51.4 | 127 |
| | | Check ..... | 104 | 48 | 46.2 | 56 | 53.8 | 62 |

Our results for the season 1913 would indicate that one spray application seven days previous to the date of infection may be fairly effective in controlling apple rust on the foliage, while an application twelve days previous was not of much value. The lime sulphur gave the best control, and Bordeaux mixture next.

The trees were in bloom April 23rd to April 27th, 1913, but the late frosts, previously mentioned, prevented securing any data as to control of rust on fruit, or effect on fruit production, of applications at blooming time.

**Field Experiments in 1914.** An orchard in Jefferson County, owned by Dr. A. P. Thompson, was secured for our work in 1914. This orchard consisted of about 300 York Imperial trees, thirteen years of age, situated along the side and top of a ridge. The trees were in good condition although they had suffered severely from rust during some of the past seasons. A large number of cedars had been cut along one side of the orchard, but there were still many of them on three sides, within ten to forty rods of it. The orchard was very free from diseases, aside from apple rust.

The general plan of the experiment may be divided into two parts. First, to apply each spray material to a few previously unsprayed trees on each day, so far as practicable, in order to determine the effectiveness of one spray application given at any specified time during the spring. The second aim was to learn whether several applications at two weeks, one week, or half week intervals would be effective in controlling the rust.

The orchard was carefully plotted and the trees tagged and numbered consecutively. The spray materials tested were atomic sulphur (7 lbs to 50 gals.); Bordeaux mixture (3 lbs. copper sulphate, and 5 lbs. lime to 50 gals.); and 35° B. home made concentrated lime-sulphur (1 to 40). The sprays were applied with a Hardie Junior power outfit, which gave very satisfactory service. A pressure of about 200 pounds was maintained. The tank, hose, and rod were washed out before placing in the tank a spray material different from the one last used.

The trees which were to be sprayed on successive dates were divided into six blocks and the trees in each block were clearly indicated by a white letter painted on the trunk of the trees. The spray to be used on any tree was indicated by one, two, or three white bands painted around the trunk. Having them marked this way saved considerable time for the man who was spraying and greatly reduced the chance of his making a mistake.

Rainy weather, and unavoidable difficulties of one kind or another rendered it impossible to carry out the full spraying schedule on the exact dates planned. The applications on these blocks were made as follows:

*Table XIV.—*Spray schedule for successive applications in 1914.*

| | No. Trees Bord. | No. Trees L. S. | No. Trees At. S. | Date Sprayed |
|---|---|---|---|---|
| Block A | 3 | 5 | 3 | Apr. 28, May 1, (L.S.), 2 (Bord. & At.S.), 4, 7, 11. |
| Block B | 3 | 4 | 3 | Apr. 28, May 1, (L.S.), 2 (Bord. & At.S.), 4, 7, 11. |
| Block C | Unsprayed trees among sprayed blocks. | | | |
| Block D | 3 | 4 | 3 | May 1, (L.S.), 2 (Bord. & At.S.), 4, 7, 11, 14. |
| Block E | 3 | 4 | 3 | April 28, May 4, 11. |
| Block F | 4 | 4 | 3 | April 28, May 4, 11, 18, 25 (Bord.), May 26 (L.S. & At.S.) |
| Block G | 3 | 5 | 3 | April 28, May 4, 11, 18. |

*L. S. stands for lime-sulphur, Bord. for Bordeaux, and At. S. for atomic sulphur. Unless otherwise stated, all sprays were applied. The spraying on block A was discontinued after May 11th, by mistake, so that blocks A and B are duplicates.

If further work is conducted along this line the spraying schedule might well be planned so that there would be no

one date when all the blocks would be treated. It so happened that the only serious rust infection of the 1914 season occurred May 5th, and all of the blocks had been sprayed on the previous day. As a result, we found no more difference between the blocks than would be accounted for by ordinary variation.

The method used in securing data from foliage will be briefly outlined. Three trees in each block were selected for **check twig** data. One of these trees was sprayed with lime-sulphur, one with Bordeaux, and one with atomic sulphur; but just before applying the spray four exposed twigs on different sides of the tree were tagged and covered with large paper sacks. As soon as the tree had been sprayed these sacks were removed. While they received none of the spray directly, it was found that they did receive an appreciable amount due to the bending down of branches higher up, combined with the action of the rain and wind. The amount of protection which such twigs secured in that way will be indicated in the next table. These four twigs were covered each time that the tree was sprayed. Four other twigs, comparable in size and exposure, were chosen on the same trees to give data as to the effectiveness of the spray. On all other sprayed trees four sprayed twigs on four sides of the tree were selected for counting. The twigs on a tree were numbered from 1 to 4 or from 1 to 8, according to whether or not there were any check twigs on it. On all check trees four twigs were taken, under similar conditions as regards size and exposure. A separate note book page was used for the data from each twig. The leaves on a twig were not counted as a whole, but the number from each bud was put down separately. This method was found very accurate and required little more time than the other. The number of spots was actually counted on each rusted leaf for at least the terminal growth of each of the eight twigs on trees which had check twigs, as shown on page 50. Similar spot counts were made on four twigs on each of ten check trees. The first two leaves to unfold, sometimes called the bud leaves, were removed before the first count was made.

As previously stated, these blocks show practically no difference in the effectiveness of the treatments as regards dates of application. It has therefore seemed advisable to omit the lengthy tabulations which would be required to show this, and to present the data from the standpoint of materials only. Table XV gives the number and distribution of rust spots on the foliage of four trees, selected to give as nearly typical and comparable results as seem possible.

TABLE XV.—*Number and distribution of rust spots on York Imperial apple foliage in Dr. A. P. Thompson's orchards during 1914.*

| | Tree Number, 320 Treatment, Atomic Sulphur, Block E | | | | | | | | | | | | | | | | Tree Number, 319 Treatment, Bordeaux, Block F | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Check twigs | | | | | | | | Sprayed twigs | | | | | | | | Check twigs | | | | | | | | Sprayed twigs | | | | | | | |
| Spur number .... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| No. of leaves.... | 9 | 8 | 11 | 10 | 8 | 5 | 7 | 7 | 12 | 8 | 8 | 11 | 13 | 7 | 8 | 7 | 5 | 9 | 4 | 6 | 9 | 5 | 10 | 7 | 10 | 9 | 4 | 8 | 7 | 11 | 8 | |
| No. of rust spots | 49 | 53 | 110 | 47 | 53 | 88 | 21 | 28 | 46 | 24 | 17 | 38 | 20 | 13 | 27 | 9 | 0 | 81 | 0 | 12 | 67 | 15 | 37 | 29 | 35 | 10 | 6 | 11 | 1 | 12 | 10 | |
| Distribution of rust spots — Leaf No. 1 | 2 | 10 | 12 | 18 | 31 | 25 | 1 | 3 | 10 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 8 | 0 | 4 | 13 | 5 | 7 | 4 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | |
| Leaf No. 2 | 6 | 18 | 24 | 8 | 17 | 19 | 4 | 9 | 6 | 11 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 15 | 0 | 1 | 19 | 6 | 8 | 14 | 1 | 3 | 3 | 0 | 0 | 0 | 2 | |
| Leaf No. 3 | 13 | 9 | 15 | 3 | 1 | 21 | 3 | 3 | 9 | 6 | 2 | 5 | 7 | 3 | 7 | 4 | 0 | 14 | 0 | 6 | 6 | 3 | 4 | 9 | 6 | 0 | 0 | 6 | 0 | 2 | 3 | |
| Leaf No. 4 | 17 | 8 | 14 | 12 | 2 | 22 | 13 | 7 | 5 | 2 | 4 | 17 | 3 | 3 | 2 | 2 | 0 | 40 | 0 | 1 | 14 | 1 | 14 | 1 | 0 | 2 | 2 | 2 | 0 | 0 | 4 | |
| Leaf No. 5 | 10 | 8 | 38 | 5 | 0 | 1 | 0 | 6 | 3 | 2 | 7 | 0 | 4 | 6 | 5 | 2 | 0 | 3 | | 0 | 8 | 0 | 0 | 1 | 1 | 3 | | 0 | 0 | 6 | 0 | |
| Leaf No. 6 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 1 | 3 | 0 | 0 | 2 | 0 | 2 | 1 | | 0 | | 0 | 4 | | 0 | 0 | 0 | 0 | | 1 | 0 | 2 | 0 | |
| Leaf No. 7 | 1 | 0 | 1 | 0 | 1 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | | 0 | | | 3 | | 0 | 0 | 0 | 0 | | 0 | 1 | 0 | 0 | |
| Leaf No. 8 | 0 | 0 | 0 | 0 | 1 | | | | 0 | 0 | 0 | 0 | 0 | | 5 | | | 0 | | | 0 | | 0 | | 0 | 0 | | 0 | | 0 | 0 | |
| Leaf No. 9 | 0 | | 0 | 0 | | | | | 0 | | | 0 | 0 | | | | | 1 | | | 0 | | 4 | | 12 | 2 | | | 0 | | | |
| Leaf No. 10 | | | 1 | 1 | | | | | 6 | | | 6 | 0 | | | | | | | | | | 0 | | 15 | | | | | 1 | | |
| Leaf No. 11 | | | 5 | | | | | | 6 | | | 8 | 0 | | | | | | | | | | | | | | | | | 1 | | |
| Leaf No. 12 | | | | | | | | | 0 | | | | 2 | | | | | | | | | | | | | | | | | | | |
| Leaf No. 13 | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | | | | |
| | Total number leaves.... 65<br>Total rusted leaves..... 45<br>Percent rusted leaves.. 69.0<br>Total rust spots.....449<br>Spots per rusted leaf.... 10 | | | | | | | | Total number leaves.... 74<br>Total rusted leaves..... 44<br>Percent rusted leaves.. 59.0<br>Total rust spots.....194<br>Spots per rusted leaf.. 4.4 | | | | | | | | Total number leaves.... 55<br>Total rusted leaves..... 31<br>Percent rusted leaves.. 56.5<br>Total rust spots.....241<br>Spots per rusted leaf.. 8 | | | | | | | | Total number leaves.... 57<br>Total rusted leaves..... 26<br>Percent rusted leaves.. 45.5<br>Total rust spots..... 85<br>Spots per rusted leaf.. 3.2 | | | | | | | |

| | Tree Number, 370<br>Treatment, Lime-sulphur, Block D. | | | | | | | | | | | | | | | | Tree Number 251<br>Check | | | | | | | | Tree Number 369<br>Check | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Check twigs | | | | | | | | Sprayed twigs | | | | | | | | | | | | | | | | | | | | | | | |
| Spur number .... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| No. of leaves.. | 7 | 6 | 5 | 5 | 7 | 5 | 9 | 5 | 4 | 6 | 10 | 8 | 3 | 5 | 6 | 7 | 7 | 6 | 8 | 6 | 5 | 4 | 8 | 6 | 9 | 4 | 8 | 8 | 9 | 5 | 7 | 6 |
| No. of rust spots | 40 | 74 | 227 | 136 | 52 | 109 | 252 | 157 | 11 | 10 | 4 | 0 | 3 | 1 | 1 | 1 | 132 | 135 | 224 | 200 | 137 | 126 | 142 | 100 | 141 | 87 | 198 | 157 | 146 | 168 | 305 | 219 |
| Distribution of rust spots | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Leaf No. 1 | 6 | 30 | 44 | 64 | 1 | 50 | 34 | 2 | 7 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 25 | 26 | 17 | 30 | 88 | 47 | 27 | 33 | 49 | 17 | 48 | 23 | 41 | 92 | 30 | 92 |
| Leaf No. 2 | 16 | 8 | 66 | 62 | 15 | 26 | 96 | 67 | 2 | 2 | 0 | 0 | 2 | 1 | 0 | 0 | 23 | 44 | 37 | 91 | 19 | 43 | 51 | 35 | 53 | 56 | 47 | 44 | 33 | 43 | 82 | 36 |
| Leaf No. 3 | 9 | 27 | 105 | 10 | 30 | 30 | 61 | 63 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 39 | 21 | 56 | 43 | 27 | 33 | 36 | 19 | 35 | 13 | 55 | 37 | 37 | 24 | 34 | 58 |
| Leaf No. 4 | 7 | 5 | 12 | 0 | 3 | 2 | 46 | 20 | 0 | 0 | 0 | 0 | | 0 | 1 | 1 | 30 | 20 | 47 | 33 | 3 | 3 | 24 | 10 | 4 | 1 | 24 | 28 | 28 | 5 | 72 | 18 |
| Leaf No. 5 | 2 | 4 | 0 | 0 | 2 | 1 | 10 | 5 | | 0 | 0 | 0 | | 0 | 0 | 0 | 14 | 22 | 50 | 3 | 0 | | 4 | 3 | 0 | | 23 | 21 | 5 | 0 | 44 | 13 |
| Leaf No. 6 | 0 | 0 | | | 1 | | 0 | | | 1 | 2 | 0 | | | 0 | 0 | 1 | 2 | 17 | 0 | | | 0 | 0 | 0 | | 1 | 4 | 0 | | 41 | 2 |
| Leaf No. 7 | 0 | | | | 0 | | 0 | | | | 0 | 0 | | | | 0 | 0 | | 0 | | | | 0 | | 0 | | 0 | 0 | 0 | | 2 | |
| Leaf No. 8 | | | | | | | 3 | | | | 0 | 0 | | | | | | | 0 | | | | 0 | | 0 | | 0 | 0 | 0 | | | |
| Leaf No. 9 | | | | | | | 2 | | | | 0 | | | | | | | | | | | | | | 0 | | | | 2 | | | |
| Leaf No. 10 | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | | | | | | |

| | | | |
|---|---|---|---|
| Total number leaves.. | 49 | Total number leaves.. | 49 |
| Total rusted leaves..... | 40 | Total rusted leaves.... | 12 |
| Percent rusted leaves | 81.6 | Percent rusted leaves | 24.5 |
| Total rust spots..... | 1047 | Total rust spots..... | 67 |
| Spots per rusted leaf.. | 20 | Spots per rusted leaf.. | 5.5 |

| | |
|---|---|
| Total number leaves.... | 50 |
| Total rusted leaves..... | 41 |
| Percent rusted leaves.. | 82 |
| Total rust spots..... | 1196 |
| Spots per rusted leaf.... | 29.8 |

| | |
|---|---|
| Total number leaves.... | 56 |
| Total rusted leaves..... | 43 |
| Percent rusted leaves.. | 77 |
| Total rust spots..... | 1421 |
| Spots per rusted leaf.... | 33 |

Table XVI shows the total results for each spray material used on the trees which were sprayed on successive dates.

Table XVI.—*Summary of rust control on York Imperial apple foliage sprayed on successive dates.*

| Number of trees | Spray | Total leaves | Rusted | | Healthy | |
|---|---|---|---|---|---|---|
| | | | Number | Percent | Number | Percent |
| **Leaves on Sprayed Twigs** | | | | | | |
| 23 | Lime-sulphur | 5493 | 1780 | 32.4 | 3713 | 67.6 |
| 18 | Bordeaux | 4257 | 1401 | 33.0 | 2856 | 67.0 |
| 18 | Atomic sulphur | 4543 | 2856 | 62.9 | 1687 | 37.1 |
| **Check Twigs** | | | | | | |
| 6 | Lime-sulphur | 1450 | 1121 | 77.4 | 329 | 22.6 |
| 6 | Bordeaux | 1384 | 845 | 61.0 | 539 | 39.0 |
| 6 | Atomic sulphur | 1580 | 1286 | 81.4 | 294 | 18.6 |
| | Unsprayed | 2030 | 1837 | 90.5 | 193 | 9.5 |

These results, secured from a number of trees and including 1300 to 5000 leaves for each treatment should give a very fair average. The lime-sulphur is evidently best, with Bordeaux a close second. The general effect of the spray on the check twigs of sprayed trees may also be noted. The average of rusted leaves on check trees was over 90% while on the check twigs of sprayed trees it falls as low as 61% in the case of Bordeaux mixture.

There was a heavy crop of apples on nearly every tree in this orchard. Data regarding the control of rust on fruit was therefore secured from a number of trees. The figures in Table XVII include both drops and picked fruit. By the term "drops" we mean, in this case, such fruits as were on the ground under the trees at picking time.

Table XVII.—*Summary of rust control on York Imperial apple fruits sprayed on successive dates.*

| Treatment | Total fruits | Rusted | | Healthy | | Number of trees | Average number fruits per tree |
|---|---|---|---|---|---|---|---|
| | | Number | Percent | Number | Percent | | |
| Check | 18622 | 13435 | 72.2 | 5187 | 27.8 | 8 | 2328 |
| Lime-sulphur | 14728 | 5602 | 38.1 | 9128 | 61.9 | 6 | 2455 |
| Bordeaux | 21956 | 10970 | 50.0 | 10986 | 50.0 | 8 | 2744 |
| Atomic sulphur | 17096 | 8962 | 52.4 | 8134 | 47.6 | 6 | 2849 |

Each of the spray materials gave a very pronounced reduction in the percent of rusted fruit, but the lime-sulphur shows up particularly well.

Turning from the trees which received several successive applications of spray, we will take up those which were sprayed but once. The dates and materials used in this part of the work are indicated below.

Table XVIII.—*Spray schedule for single application in 1914.*

| Date | Number of trees sprayed | | |
|---|---|---|---|
| | Bordeaux | Lime-sulphur | Atomic sulphur |
| April 28 | 3 | 3 | 3 |
| April 29 | | 3 | |
| May 1 | | 3 | |
| May 2 | 3 | | 1 |
| May 4 | 3 | 3 | 3 |
| May 5 | 7 | 2 | |
| May 6 | 3 | 7 | 7 |
| May 7 | 3 | 3 | 3 |
| May 8 | | 3 | |
| May 9 | 3 | | 3 |
| May 11 | 1 | 1 | 1 |
| May 12 | 3 | 3 | 3 |
| May 13 | 3 | 3 | |
| May 14 | 3 | 3 | |
| May 15 | 3 | 3 | |
| May 18 | 3 | 3 | |
| May 19 | | 3 | |
| May 20 | 3 | 3 | |
| May 21 | 3 | 3 | |
| May 22 | 3 | 3 | |
| May 23 | 3 | | |
| May 25 | 3 | 3 | |
| May 26 | 2 | 2 | |
| May 28 | 2 | 2 | |

Check twigs were retained on each of the trees used. Since there was no important rust infection after May 5th, counts were made only on trees sprayed previous to that date. Table XIX shows the effectiveness of the treatments.

Table XIX.—*Rust control on York Imperial apple foliage as a result of single spray applications in 1914.*

| Tree number | Date | Spray | Total number | Rusted | | Healthy | |
|---|---|---|---|---|---|---|---|
| | | | | Number | Percent | Number | Percent |
| **Leaves on Sprayed Twigs** | | | | | | | |
| 43 | April 28 | Lime-sulphur | 215 | 183 | 85.0 | 34 | 15.0 |
| 44 | April 28 | Atomic sulphur | 306 | 229 | 75.0 | 77 | 25.0 |
| 45 | April 28 | Bordeaux | 251 | 151 | 60.0 | 100 | 40.0 |
| 242 | April 29 | Lime-sulphur | 273 | 156 | 27.0 | 118 | 43.0 |
| 204 | May 1 | Lime-sulphur | 289 | 174 | 60.0 | 115 | 40.0 |
| 191 | May 1 | Bordeaux | 260 | 144 | 55.4 | 106 | 44.6 |
| 219 | May 1 | Atomic sulphur | 232 | 166 | 71.0 | 66 | 29.0 |
| 249 | May 2 | Lime-sulphur | 312 | 145 | 46.5 | 167 | 53.5 |
| 221 | May 2 | Bordeaux | 222 | 93 | 42.0 | 132 | 58.0 |
| 4 | May 4 | Lime-sulphur | 334 | 88 | 26.5 | 246 | 73.5 |
| 5 | May 4 | Atomic sulphur | 279 | 132 | 48.0 | 147 | 52.0 |
| 7 | May 4 | Bordeaux | 348 | 63 | 18.0 | 285 | 82.0 |
| **Leaves on Checked Twigs** | | | | | | | |
| 42 | | Check | 186 | 161 | 87.0 | 25 | 13.0 |
| 43 | April 28 | Lime-sulphur | 201 | 147 | 73.0 | 54 | 27.0 |
| 44 | April 28 | Atomic sulphur | 227 | 174 | 76.5 | 53 | 23.5 |
| 45 | April 28 | Bordeaux | 325 | 215 | 66.0 | 110 | 34.0 |
| 242 | April 29 | Lime-sulphur | 230 | 185 | 81.0 | 45 | 19.0 |
| 204 | May 1 | Lime-sulphur | 230 | 202 | 88.0 | 28 | 12.0 |
| 191 | May 1 | Bordeaux | 261 | 220 | 84.1 | 41 | 15.8 |
| 219 | May 1 | Atomic sulphur | 194 | 163 | 84.0 | 31 | 16.0 |
| 249 | May 2 | Lime-sulphur | 147 | 127 | 86.4 | 20 | 13.6 |
| 221 | May 2 | Bordeaux | 168 | 126 | 75.0 | 42 | 25.0 |
| 4 | May 4 | Lime-sulphur | 247 | 176 | 72.0 | 71 | 28.0 |
| 5 | May 4 | Atomic sulphur | 247 | 151 | 62.0 | 96 | 38.0 |
| 7 | May 4 | Bordeaux | 293 | 147 | 50.0 | 146 | 50.0 |
| 223 | | Check | 162 | 153 | 95.0 | 9 | 5.0 |

The results of these trials would indicate that a spray application one week previous to infection is ineffective for control of rust, while the same material applied one day previously is very effective and applied three days previously is fairly effective.

The data for 1912 indicated practically the same thing. The date of infection in 1914 was almost the same as in 1912 and the date of blooming for the trees in 1912 was about May 2-5, while in 1914 it was May 1-5. The blossom buds were just showing good color on April 27th, and the so-called cluster bud spray was being applied at that time in a nearby orchard. A large portion of the central blossom buds opened

on May 1st. May 4th, practically every blossom had opened and during that day a very few petals fell from the earlier blossoms. It was impossible to spray until about noon, on May 5th, and applications made at that time showed no control of rust. The only time when spray could have been effectively applied for the control of apple rust in 1914 was when the trees were in bloom.

The conclusion which we would draw from these spraying experiments is that the disease is readily controlled by the common spray mixtures such as lime-sulphur, Bordeaux mixture, and atomic sulphur; that lime-sulphur is most efficent; and that a successful spray schedule for rust control must take into account the rate of growth of the young leaves. We do not believe that the apple rust disease can be consistently and regularly controlled by the use of less than six or seven applications during the spring. Such a spraying schedule would be about as follows:

First Application—When blossom buds are showing good color. (Arsenate might be included.)

Second Application—Within one or two days after first blossoms open. (No arsenicals.)

Third Application—As soon as ½ to ⅔ of bloom has dropped. (No arsenicals.)

Fourth Application—3 to 4 days after third. (Include arsenate.)

Fifth Application—5 to 6 days after fourth. (No arsenicals.)

Sixth Application—5 to 6 days after fifth. (No arsenicals.)

Seventh Application—6 to 7 days after sixth. (No arsenicals.)

The second, third, fourth, fifth, and sixth are believed to be the most important. **The spraying must, of course, be thoroughly done, and the impracticability of carrying out such a spray schedule in a large orchard is self evident.**

A glance at the last column in Table XVII will show that there were more fruits matured upon the trees sprayed May 4th, in full bloom, than upon the check trees. Many young fruits may have been killed, but the trees still needed thinning. From our experiments thus far, we would not hesitate to recommend that York Imperial apple trees, showing a good amount of bloom, should receive one spray appli-

## PLATE IX.

Fig. 1—Cedar trees scattered in with other growth at Falling Waters, W. Va.

Fig. 2—Instrument shelter for hygrothermograph, showing exposure.

Fig. 3—Cedar trees in pasture field near Inwood, W. Va.

cation of lime-sulphur without arsenical poison while they are in bloom, provided the apple rust is prevalent and destructive in that section.

So far as we have been able to learn, there is no evidence that the lime-sulphur spray would be injurious to bees visiting the blossoms after this spray has been applied.

## DESTRUCTION OF RED CEDARS AS A METHOD OF CONTROL.

The destruction of the red cedar has been quite universally recommended as the best and most practical method of controlling apple rust. Although this method of control is so generally accepted we find only one reference to a careful experiment for determining its efficiency. Jones (1893, p. 83) as quoted on page 6, secured some definite evidence regarding this point.

Reed (1914, p. 23) gives reports from orchard men as to the effectiveness of cutting out cedars, but details as to distances, area, etc. are not mentioned.

The value of the cedars must be taken into consideration when dealing with a problem of this kind. The red cedar, *Juniperus virginianae* is of very little commercial importance in West Virginia. It occurs quite commonly throughout the state and is abundant in some of the principal apple growing sections. Most of the growth is of no value because of its inferior, bushy development. There are many fields which

2

3

should be cleared of these scrub cedars because of the increased pasture value which would result. (Plate IX, fig. 3.) The larger trees find use as fence posts and telephone poles, but comparatively few are valuable for sawed lumber, and it is said that only the red, heart wood is good for fence posts. The sentimental value which may be attached to cedars is often a factor of great importance, and is far more difficult to deal with than a mere commercial value. There are very few places where the value of an orchard would not greatly outweigh the value of all the red cedar trees to be found within such range that they would be likely to produce serious rust infection.

The very destructive apple rust infection of 1912 brought this disease to a conspicuous place in the list of apple enemies, and during the year 1913 the State Crop Pest Commission took action in regard to the destruction of red cedars in certain sections of West Virginia. The state law, governing such matters, granted this commission authority to make the necessary rules and regulations likely to be required for any case of this kind.* Rules relative to the destruction of red cedars, harboring this disease, were issued in February, 1913, and the agents of the commission began active work in November, 1913.

Of course every reasonable effort was used to have the cedars removed without a direct application of the processes of law. Difficulties were met with and overcome, and much valuable work has been accomplished along this line.†

The cost of cutting out cedars is often given as an argument against the general application of this method. Mr. S. L. Dodd, Jr.‡ has secured some valuable data for us along this line, showing the actual cost of such work. This cedar destruction was carried on in Berkeley County, West Virginia. The facts are given in some detail, since it is essential to know the conditions under which the work was done. Mr. Dodd's report is as follows:

"The first locality where much work was done is at Tablers Station on the lands adjoining the orchards

*Copies of the state law, and the special rules of the State Crop Pest Commission may be secured from the State Entomologist, Morgantown, W. Va.

†Further details in regard to this work are given by W. E. Rumsey in the First Biennial Report of the State Crop Pest Commission.

‡S. L. Dodd, Jr. is the State Crop Pest Commission inspector for Berkeley County. He is well acquainted with conditions in that section, and has had personal charge of much of the cutting out work.

of C. C. Borum, J. W. Stewart, and Lord & Harrison. At this point approximately 350 acres have been cleared of cedars and there remain about 225 acres to clear yet. Of the 350 acres cleared, about 100 acres were in wood lot where the cedars were overrun with grape vines, and the underbrush was heavy, thus making the cutting more expensive and much harder. The other 250 acres were cleared much cheaper as the trees were for the most part located in fence rows and on rock breaks in the fields. These cedars were nearly all from 15 to 25 feet in height although there may have been 20% which were smaller (from two to ten feet). In the wood lot the trees were very thick, while in the fence rows they were more scattered. On 250 acres of this land nine men were employed two days, seven of them receiving $1.00 and the other two who were inspectors, $3.00 per day. Eleven men were employed two days clearing another fifty acres. Eight of these men were paid at the rate of $1.00 per day, two at $3.00 and one at $2.00. Twenty-five more acres required ten men for two days, seven men at $1.00 per day, two at $3.00 and one at $2.00; while on the remaining twenty-five acres two were employed eight days, one at $3.00 and one at $2.00 per day. This makes a total of $128.00 for the 350 acres. On the 250 acres in fence rows and breaks the cedars were trimmed up and the brush piled ready to be burned.

"The second place which should be mentioned is at Darkesville on lands adjoining the McDonald orchard. There was some cutting done in this locality by the property owners, but the cost is not obtainable, and that area is not included. There were 200 acres in the place where we did the cutting and the cedars were scattered over the whole of it, in fence rows and on rock breaks. In this case the trees were trimmed up and the brush piled and I think burned. These trees were mostly very large, being from twenty to twenty-five feet in height. A few along the fence row in one field were very small. Six men were employed six days; four of them receiving $1.25, and the other two $3.00 per day. This makes a total of $66.00 to clean up the 200 acres.

"The third place where extensive cutting was done is around the Cherry Hill Orchard Company's place in Falling Waters District. We have cut the cedars on about 200 acres but there are still about 600 acres which should be cleared. On 100 acres of the land cut over last year the cedars were small, being from two to six feet in height, and were scattered over large open fields. On the other 100 acres the trees

## PLATE X.

Meteorological instruments, showing equipment and exposure.

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were larger, being from 15 to 20 feet in height, and about half of them were in a wood lot while the rest were in fields and around fence rows.

"On the first 100 acres two men were employed six days, one at three and the other at two dollars. On the last 100 acres two men were employed five days at the same rate of pay as before. In this case we trimmed up the trees and left them in poles. We began cutting again at this place a few days ago and about 5 acres were cleared by one man in one day, at $3.00 per day. A total of $58.00 has been spent in cutting out the cedars from 205 acres at this place.

"The next locality where work was done is in Falling Waters District around the orchards of Mr. George Ryneal, Jr. The cedar trees here were all large, running from twenty to thirty feet in height. Most of them were located on the river cliff, and in with other timber. Owing to the fact that the ground is quite high at this point the spores from these trees would blow over a very large area, making it particularly important to have them removed. Twenty-five acres of this land had the cedars scattered along fence rows and on rock breaks. More than half of the trees have been cut by the owner without any help from the state whatsoever. This man also helped when we were cutting in that neighborhood. There have been about 65 acres cleared of cedars at this point. On the first 25 acres four men were employed ten days and were paid $1.25 per day. On the remaining 40 acres five men were used for six days, four at $1.25, and one at $2.00, making a total of $92.00.

E
W

"At Ridgeway we did some cutting around the Clohan orchards which are about a mile from the station. On one farm we cleared out a thicket composed almost entirely of cedars. These trees were very tall and straight and in order to get them cut we had to trim them into poles and pile the brush. This thicket stood about three-fourths of a mile from the Clohan orchard and was on the western side on high ground. As the winds come mostly from this direction it was very important to remove the cedars.

"There are about seven or eight acres in the clearing and it took four men, ten days to complete the job. One of these men received $3.00, another $2.00 and the other two men $1.25 each per day. This makes a total of $75.00 to finish the work at that place.

"The cedars were also destroyed on about 100 acres close around this orchard. The trees here were from fifteen to twenty feet in height and located along the fences. On this there were five men employed for three days. Three received $1.25, one $2.00 and one $3.00 per day, which makes a total of $26.25 in all. In this case we again trimmed up the trees and piled the brush.

"The cedars were also cleared from 15 acres of wood lot. The trees were 10 to 15 feet tall and the largest of them were trimmed up for posts. Six men were employed for one day. Four of them received $1.25 each, one $2.00 and the other $3.00 per day, making a total of $10.00.

"At Parks Gap on Dry Run Pike, around the orchards of J. H. Fishell, S. S. Felker and the Sperows, about 150 acres were cleared. On twenty-five acres of this the trees were small and in the open field at the foot of the mountain. The cedars on the remaining 125 acres were larger and were on the mountain, making it very hard to cut them. One man at $2.00 per day was employed for six days to cut the twenty-five acres. On the other 125 acres four men were employed five days. Two of them were paid $1.25 each, one $3.00 and one $2.00 per day. The last trees were trimmed up and left in poles. They were mostly about fifteen to twenty feet in height. The total cost in this case was $49.50.

"The Pittsburgh Orchards Co. of Hedgesville report cutting the cedars from 21.2 acres at a cost of $19.93. The trees were mostly fifteen to twenty feet tall and varied from

sparse to thickly clustered clumps with many grape vines among them. The time required to do this work was 152½ hours and the average rate of pay per hour was 13c. They say, 'In our experience the cutting of cedars is inexpensive and rapid work, and were the cost increased an hundredfold, it would be insignificant in comparison with the benefit established.'

"This data is as near accurate as I am able to get it, and hope that it will serve your purpose. You will understand that this is the cost of cutting only, and not the cost of marking and the numerous trips in order to get the owners consent to do the cutting.

"There are other places where cutting has been done, but I have no information as to the cost. There are also a great many places where we cut a day or so, but the work is so incomplete that it would be unwise to include it in this report. In many cases we simply got the trees marked but none cut."

Table XX.—*Cost of destroying cedar trees.*

| Acres cleared* | Days required | No. men employed | Average rate per day per man | Total cost |
|---|---|---|---|---|
| 250 | 2 | 9 | $1.44 | $ 26.00 |
| 50 | 2 | 11 | 1.49 | 32.00 |
| 25 | 2 | 10 | 1.50 | 30.00 |
| 25 | 8 | 2 | 2.50 | 40.00 |
| 200 | 6 | 6 | 1.83 | 66.00 |
| Picking galls | 4 | 1 | 2.00 | 8.00 |
| 100 | 6 | 2 | 2.50 | 30.00 |
| 100 | 5 | 2 | 2.50 | 25.00 |
| 5 | 1 | 1 | 3.00 | 3.00 |
| 25 | 10 | 4 | 1.25 | 50.00 |
| 40 | 6 | 5 | 1.40 | 42.00 |
| 7.5 | 10 | 4 | 1.87 | 75.00 |
| 100 | 3 | 5 | 1.75 | 26.25 |
| 25 | 6 | 1 | 2.00 | 12.00 |
| 125 | 5 | 4 | 1.87 | 37.50 |
| 15 | 1 | 6 | 1.67 | 10.00 |
| 21.2 | 152.5 hrs. | | 1.30 | 19.93 |
| 1113,7 | | | | $532.68 |

*By the term, "acres cleared," we mean only such land as was actually included in a general cedar growth, such as a grove or wood lot; and, in the case of fence row trees, the immediately adjacent field which they bounded. This is possibly clearer in the previous detailed statements.

The total time required for this work was 311 days and the average rate of pay was $1.71 per day. The average cost per acre was less than 48 cents.

From these figures it would appear that, under average conditions such as exist in Berkeley County of West Virginia,

the actual cost of removing cedar trees for a radius of one mile around an orchard of 600 or more susceptible trees would be about equal to the fruit loss which might be expected to occur in one season as the result of a severe infection of apple rust. In other words, it is quite possible that one season's increased profit resulting from cedar tree destruction will entirely pay for the cost of cleaning up the cedars.

The cutting out which was done during the winters of 1910-11 and 1911-12 undoubtedly saved much of the York Imperial apple crop from complete destruction in at least two large orchards in 1912. In so far as we know, these two orchard are the only ones around which there had been any active and systematic work in cedar tree destruction. Good results have also been secured from the more recent work along this line. Mr. Dodd, in his report, says, "At none of the places mentioned in my report have all the cedars been cut back to one-half mile and in some places they are up against orchard fences.

"In several instances our cedar cutting of last year brought good results, but this was because the cedars happened to be cut on the side from which the wind blew at the time the spores spread."

In this connection it is worthy of note that we know of only one commercial orchard around which the cedars have been destroyed within a radius of about one mile. This orchard suffered from a very severe rust infection in 1912, and the owner spared no effort to follow out our recommendations as to cedar tree destruction. By the spring of 1914 there appeared to be no cedars within three-fourths of a mile, and there were not many within a mile of this orchard. During the summer of 1914 a large number of the commercial orchards in that section were visited, and the amount of rust in the above mentioned orchard was very small, as compared with the others. There was a scattered infection throughout the orchard, but that was to be expected.

We have been recommending that all cedars be cut for a radius of one mile around orchards, and from the records at hand the range does not appear to have been set too far. Records from one orchard around which the owners felt that cedar cutting had been quite well done show first, that considerable of the foliage on Rome Beauty trees had ten or more rust spots per leaf; second, that many of these leaves

were falling about the 1st of August; third, the nearest cedar trees were about 2300 feet from these Rome Beauty trees, and it is likely that most of the infection came from trees which were at least three-fourths of a mile away. The cedars were on slightly elevated ground, but not much above the orchard level. Observations in a number of other orchards indicate that a half mile cedar free range is not sufficient to prevent serious infection under West Virginia conditions. When even a very small percentage of the leaves have ten or more rust spots each, the infection is considered serious and a glance at Tables II and III will convince almost any reader that we have set our present limit several spots too high.

Some additional facts in regard to the range of infection have been given on page 30.

## DESTRUCTION OR PREVENTION OF RUST GALLS ON CEDAR AS A MEANS OF CONTROL.

Cedar trees around a house are sometimes highly valued and the owners often desire to remove the rust galls instead of destroying the trees. It is possible that this practice may be effectively carried out in some cases, but it is a most tedious operation, and must be repeated year after year if good results are to be secured. We have records of several cases where it has been tried and abandoned. A man will usually revise his ideas as to the value of a cedar tree by the time he has spent ten to fifteen hours picking rust galls from it.

The spraying of cedars as reported by Heald (1909, p. 112) would doubtless be far more practical for the treatment of cases of this kind. This department has not conducted any experiments in the spraying of cedar trees.

## SUSCEPTIBILITY OF APPLE VARIETIES.

Many lists have been published, giving data on the susceptibility or resistance of different varieties as they have been observed in various sections of the country. Table XXI gives some of the more important varieties and their susceptibility as listed by different states. Four signs are used to indicate varying degrees of susceptibility or immunity. 3 indicates susceptible, 2 indicates moderately susceptible, 1 indicates resistant, 0 indicates immune.

Table XXI.—*Susceptibility of apple varieties to rust as reported by different states.*

| | Alabama | Connecticut | Delaware | Indiana | Iowa | Maryland | Massachusetts | Minnesota | Nebraska | New Hampshire | New York | North Carolina | Rhode Island | Pennsylvania | South Carolina | Virginia | West Virginia | Wisconsin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arkansas Black | | | 0 | | | 1 | | | | | | 1 | | | | | 0 | |
| Baldwin | | 1 | | | | | 1 | | | | 1 | | 1 | | | | 0 | |
| Ben Davis | | | 1 | | 3 | | 1 | | 1 | | | | 1 | | | 3 | 2 | |
| Black Twig | 1 | | 0 | | | | | | | | | | | | | 1 | 1 | |
| Bonum | | | 3 | | | | | | | | | 3 | | | | 3 | | |
| Fameuse | | | | | 1 | 3 | | | | | | | | | | | | 1 |
| Fallawater | | | 3 | | | | | | | | | 3 | | | | | | |
| Grimes | 2 | 1 | 3 | 1 | 3 | 1 | | | 1 | | | | | | 3 | 1 | 1 | |
| Jonathan | 3 | | | 3 | 1 | | | | 3 | | | | | 3 | | 3 | 3 | 2 |
| Maiden Blush | 1 | | 1 | | | 3 | | | 1 | | | | | | | | 1 | |
| Northern Spy | | | | | | | | | | | | | | | | 3 | | |
| N. W. Greening | | 1 | | | | | | | | | | | | | | 1 | 2 | 1 |
| Red June | 3 | | 0 | | | | | | 3 | | | 3 | | | 3 | | | |
| Red Astrachan | 1 | | 0 | | | 1 | 1 | | 1 | | | | 1 | | | | | |
| Rome | 3 | | 0 | 3 | | 3 | | | | | | 3 | | 3 | | | 3 | |
| Shockley | 3 | | | | | | | | | | | 3 | | | 3 | | | |
| Stayman | | | 0 | | | | | | | | | 1 | | | | 1 | 0 | |
| Wealthy | | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | | 3 | | | | 3 | 3 |
| Winesap | 1 | | | | | 1 | | | 1 | | | 1 | | | | 1 | 0 | |
| Yellow Transparent | | | 0 | | | 1 | 1 | | 1 | | | | 1 | | | | 0 | |
| York Imperial | 2 | | | | | | | | | | | 1 | | 3 | | 3 | 3 | |

Some varieties are listed as susceptible in one state and resistant in another. While there is undoubtedly some variation due to the difference in location, we are inclined to think that the judgment of the individual as to what constitutes resistance or susceptibility is a more important factor. Observations made upon single trees are sometimes misleading, since noticeable variation is often apparent among trees of the same variety. Different periods of rust infection may also give rise to confusing data, because the leaves of one variety may expand more quickly, or have a shorter period of susceptibility than the leaves of another variety.

From the data at hand we would give the following list for West Virginia:

| Susceptible | Moderately Susceptible | Resistant | Immune |
|---|---|---|---|
| York Imperial | Ben Davis | | Baldwin |
| Rome | N. W. Greening | Black Twig | Winesap |
| Wealthy | | Grimes | Ark. Black |
| Jonathan | | Maiden Blush | Stayman |
| | | | Yellow Transparent |

## SUMMARY AND CONCLUSIONS.

The meteorological conditions which help to bring about apple rust infection should receive further careful study. This laboratory is conducting some investigations along that line.

Apple leaves are susceptible only when young, and a destructive rust infection is not likely to take place after the first week in June, at this latitude.

A severe rust infection results in deformed fruit, a general reduction in size of fruit, and great loss of vigor on the part of the tree. There is a very distinct relationship between the number of rust spots on a York Imperial apple leaf and the length of time the leaf is retained by the tree.

This disease may be controlled by the use of spray materials, but it seems impracticable for the commercial orchardist.

The destruction of cedar trees has been found an effective means of control; but the work must be thoroughly done; and, under most conditions we believe that the cedar-free area should cover a radius of at least one mile around an orchard. The cost of cutting out cedars has been found to be comparatively small. An area including 1113 acres was cleared at an expenditure of $532.68, which was less than 48 cents per acre.

There is extreme range of susceptibility among apple varieties, and even different trees of the same kind show appreciable variation.

The detailed records covering our work on this disease are on file at this Experiment Station, and access may be had to them by anyone interested in work along that line.

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West Virginia University
Agricultural Experiment Station
MORGANTOWN, W. VA.

DEPARTMENT OF SOILS

# Experiments With Fertilizers

No Fertilizers HAY 1915 Fertilizer

BY
FIRMAN E. BEAR

# THE STATE OF WEST VIRGINIA

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## FERTILIZER FACTS.

Summarized from 15 years' experiments at the West Virginia Agricultural Experiment Station on the basis of crop values assumed in this bulletin.

1. Every ton of manure applied alone has produced an increase per ton, valued at $3.12.

2. Every dollar's worth of acid phosphate applied alone has given an average of $4.63 worth of increase.

3. Every dollar's worth of nitrate of soda applied alone has given an average of $.34 worth of increase.

4. Every dollar's worth of sulphate of potash applied alone has given an average of $.37 worth of increase.

5. Nitrate of soda and acid phosphate applied in combination have given 2¼ times as much increase per acre as acid phosphate alone, and $2.19 worth of increase for every dollar invested.

6. Nitrate of soda, sulphate of potash and acid phosphate applied in combination have given three times as much increase per acre as acid phosphate alone and $2.32 worth of increase for every dollar invested.

7. Every dollar invested in lime and applied in connection with complete fertilizer has given an increase valued at $1.35.

| PLOT | DIAGRAM OF FERTILITY PLOTS<br>PLOTS ONE-TENTH ACRE EACH |
|---|---|
| 18 | No Fertilizer |
| 19 | Nitrate of Soda, Acid Phosphate, Sulphate of Potash, Lime |
| 20 | Manure and Lime |
| 21 | No Fertilizer |
| 22 | Lime |
| 23 | Ash of Manure and Nitrate of Soda |
| 24 | No Fertilizer |
| 25 | Manure |
| 26 | Nitrate of Soda, Acid Phosphate and Sulphate of Potash |
| 27 | No Fertilizer |
| 28 | Acid Phosphate and Sulphate of Potash |
| 29 | Nitrate of Soda and Sulphate of Potash |
| 30 | No Fertilizer |
| 31 | Nitrate of Soda and Acid Phosphate |
| 32 | Sulphate of Potash |
| 33 | No Fertilizer |
| 34 | Acid Phosphate |
| 35 | Nitrate of Soda |
| 36 | No Fertilizer |

# Experiments With Fertilizers

By FIRMAN E. BEAR

The West Virginia Agricultural Experiment Station has conducted a series of fertilizer experiments since 1900 on the Experiment Station farm at Morgantown. Three bulletins, numbers 99, 112 and 131, have been published, giving the results of the fertilizer tests. The present publication is intended as a summary of the former bulletins together with additional data secured since the publication of Bulletin No. 131.

## Plan of the Experiments.

The original plan of these experiments was devised by Horace Atwood. A part of the station farm lying along the Morgantown and Pt. Marion pike was laid off in tenth acre plots. Each plot was made two rods wide and eight rods long with a three foot space between plots. The plots were numbered serially from 18 to 36. In order to determine whether there was any in-equality in the soil every third plot was left unfertilized. Accordingly, plots 18, 21, 24, 27, 30, 33 and 36 are no-fertilizer, or check plots. Three of these check plots have been discarded as checks.

The tile drain passing near plot 18 became stopped up and the yields were abnormal.

Plot 24 had been used as a check until 1913 when by mistake this plot was given an application of manure intended for plot 25. Although the manure was raked off with a hand rake a few days later, the plot was ruined as a check plot. The yield of wheat on this plot in 1914 was 19.83 bushels per acre as compared to 5.92 bushels, the average of the other check plots. The yield of hay on plot 24 in 1915 was 2,660 pounds per acre as compared to 198 pounds, the average of the other checks.

It became necessary to discard plot 36 because this plot had a tendency to wash and did not give a fair check.

In the original report of the experiments the increase produced by the use of fertilizer was computed by taking the

average of the two nearest check plots and subtracting this from the yield of the fertilized plot. Since three of the check plots were discarded it was found necessary to take the average of all the remaining checks and subtract this from the yield of the plots receiving fertilizer.

The yield of the remaining check plots indicate that the soil is naturally fairly uniform in productivity. The total produce of these check plots since 1900 is as follows:

| | Pounds Produce |
|---|---|
| Plot 21 | 38,500 |
| Plot 27 | 41,940 |
| Plot 30 | 39,250 |
| Plot 33 | 36,615 |

The soil on which these fertilizer tests are being conducted is mapped by the U. S. Bureau of Soils as Dekalb silt loam. It has been formed by the disintegration of the grayish shales and fine grained sandstone overlying the Pittsburg vein of coal. The soil is naturally well drained, and easily tilled but has a tendency to dry out too rapidly. It is only moderately productive normally but can be made very productive if well treated. The original timber consisted mostly of oak and chestnut.

### The Crops Grown.

No definite rotation was adopted but a variety of crops were grown in order to determine the effect of fertilizer treatment on a number of different crops.

Since 1900 there have been three crops of corn, two crops each of timothy, rye, clover, and wheat and one crop each of oats, cowpeas, potatoes, and timothy and clover mixed.

### Fertilizer Treatment.

In order to magnify the effect and overcome the element of time to a certain extent, very liberal applications of fertilizer were made. The first application of fertilizer was made in the spring of 1900 as a top dressing on rye. Later applications have been made with a fertilizer drill, the fertilizer being applied immediately before planting the seed. In 1902 for the crop of clover, in 1907 for the crop of rye, and in 1908 and 1914 when the plots were seeded to timothy and clover no fertilizer was applied to any of the plots. The first year the carrier of phosphoric acid was Thomas slag, since then acid phosphate has been used.

The following shows the amount and kind of fertilizer applied annually to each plot, with the exceptions noted:

Plots 18, 21, 24, 27, 30, 33 and 36. No fertilizer.

Plot 19. 40 pounds sodium nitrate; 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906); 100 pounds lime in 1900, 150 pounds lime in 1906 and 200 pounds lime in 1912.

Plot 20. Two tons stable manure; 100 pounds lime in 1900, 150 pounds lime in 1906, and 200 pounds lime in 1912.

Plot 22. 100 pounds lime in 1900 and in 1903, 150 pounds in 1906, and 200 pounds in 1912.

Plot 23. Ash from two tons of stable manure, together with an amount of nitrogen in the form of sodium nitrate equivalent to the nitrogen originally present in the stable manure. Applications made in 1900 and in 1901. Since then no further applications until 1912 when it received 40 pounds of a 4-16-4 fertilizer.

Plot 25. Two tons stable manure applied annually except in 1903.

Plot 26. 40 pounds sodium nitrate; 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906.)

Plot 28. 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906).

Plot 29. 40 pounds sodium nitrate; 15 pounds potassium sulphate (20 pounds in 1906).

Plot 31. 40 pounds acid phosphate; 40 pounds sodium nitrate.

Plot 32. 15 pounds potassium sulphate (20 pounds in 1906).

Plot 34. 40 pounds acid phosphate.

Plot 35. 40 pounds sodium nitrate.

1902, 1907, 1908, 1914 and 1915 no fertilizer applied on any of the plots.

1913 only ½ of original applications of fertilizer.

## Total Amounts of Fertilizers Applied Per Acre From 1900 to 1915 Inclusive.

| Plot | Nitrate of Soda Pounds per Acre | Acid Phosphate Pounds per Acre | Sulphate of Potash Pounds per Acre | Lime Pounds per Acre | Manure Tons per Acre |
|---|---|---|---|---|---|
| 19 | 4200 | 4200 | 1625 | 4500 | |
| 20 | | | | 4500 | 210 |
| 21 | | | | | |
| 22 | | | | 5500 | |
| 23 | 30 Ash of 40 tons of manure until 1912 | | | | |
| 24 | | | | | |
| 25 | | | | | 190 |
| 26 | 4200 | 4200 | 1625 | | |
| 27 | | | | | |
| 28 | | 4200 | 1625 | | |
| 29 | 4200 | | 1625 | | |
| 30 | | | | | |
| 31 | 4200 | 4200 | | | |
| 32 | | | 1625 | | |
| 33 | | | | | |
| 34 | | 4200 | | | |
| 35 | 4200 | | | | |

Plot 19
Lime and Fertilizer
5800 lbs. Hay

Plot 20
Lime and Manure
7400 lbs. Hay

Plot 21
No Fertilizer
100 lbs. Hay

Plot 22
Lime
750 lbs. Hay

Plot 28
Acid Phosphate
Sulphate of Potash
1440 lbs. Hay

Plot 29
Sulphate of Potash
Nitrate of Soda
360 lbs. Hay

Plot 31
Nitrate of Soda
Acid Phosphate
2590 lbs. Hay

Plot 34
1030 lbs. Hay
Acid Phosphate

## POUNDS OF PRODUCE PER ACRE.

| Plot | FERTILIZER | 1900 RYE | | 1901 WHEAT | | 1902 CLOVER | 1903 CORN | | 1904 COW PEAS | 1904 CORN | 1906 POTATOES | 1907 RYE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Grain | Straw | Grain | Straw | Hay | Grain | Stover | Hay | Ensilage | Tubers | Grain | Straw |
| 19 | N, $K_2O$, $P_2O_5$, Lime | 2076 | 3524 | † 1665 | 3760 | 6700 | 6200 | 6800 | 6950 | 27700 | 6120 | 1170 | 3030 |
| 20 | Manure, Lime | 1578 | 2762 | 1840 | 4560 | 8850 | 7700 | 9400 | 6750 | 34700 | 13060 | 2140 | 4860 |
| 21 | No Fertilizer | 1186 | 2064 | 1140 | 1160 | 2050 | 2000 | 3800 | 1250 | 11200 | 2600 | 140 | 360 |
| 22 | Lime | 1077 | 1813 | 1010 | 1490 | 1500 | 1620 | 3200 | 1200 | 9800 | 1520 | †130 | 330 |
| 23 | Ash of Manure, N | 2095 | 4845 | 1880 | 3320 | 7900 | 4410 | 5800 | 2750 | 15300 | 2500 | 170 | 280 |
| 24 | No Fertilizer | 1100 | 2070 | 1070 | 1830 | 2100 | 1770 | 3650 | 1350 | 12100 | 2610 | 140 | 380 |
| 25 | Manure | 1913 | 3587 | 1920 | 4580 | 9550 | 5230 | 6500 | 6100 | 34800 | 11300 | 1880 | 4420 |
| 26 | N, $K_2O$, $P_2O_5$ | 2463 | 4317 | 1750 | 3950 | 7250 | 5620 | 7000 | 6300 | 29000 | 7030 | 1170 | 2530 |
| 27 | No Fertilizer | 1297 | 2583 | 1120 | 1780 | 2850 | 1980 | 3450 | 2200 | 12500 | 2850 | 160 | 290 |
| 28 | $P_2O_5$, $K_2O$ | 1411 | 2739 | 1550 | 3350 | 5500 | 5160 | 6200 | 4400 | 16100 | 6360 | 850 | 1850 |
| 29 | N, $K_2O$ | 1980 | 3560 | 1080 | 1820 | 2000 | 1500 | 3300 | 2300 | 15000 | 3520 | 140 | 260 |
| 30 | No Fertilizer | 1340 | 2540 | 1050 | 1650 | 2650 | 1820 | 3600 | 2100 | 10900 | 2140 | 160 | 250 |
| 31 | N, $P_2O_5$ | 2267 | 4153 | 1550 | 3350 | 7900 | 5400 | 7000 | 5150 | 18900 | 3830 | 1020 | 2270 |
| 32 | $K_2O$ | 1402 | 2678 | 1030 | 1670 | 2500 | 2000 | 3750 | 1950 | 11800 | 2630 | 140 | 360 |
| 33 | No Fertilizer | 1330 | 2600 | 1110 | 1990 | 2200 | 1930 | 3600 | 2450 | 8700 | 2400 | 120 | 280 |
| 34 | $P_2O_5$ | 1360 | 2810 | 1390 | 2610 | 5400 | 4570 | 5750 | 3650 | 14100 | 3800 | 770 | 1930 |
| 35 | N | 1914 | 3716 | 930 | 1770 | 2600 | 1330 | 3300 | 2500 | 10200 | 2250 | 210 | 290 |

*Plots sown to timothy and clover but on account of unfavorable weather very poor crop in 1908. Plots were mowed and hay left on ground.

†Calculated yields.

## POUNDS OF PRODUCE PER ACRE (Continued).

| Plot | FERTILIZER | 1909 TIMOTHY & CLOVER Hay | 1910 TIMOTHY Hay | 1911 TIMOTHY Hay | 1912 CORN Grain | 1912 CORN Stover | 1913 OATS Grain | 1913 OATS Straw | 1914 WHEAT Grain | 1914 WHEAT Straw | 1915 CLOVER Hay | TOTAL PRODUCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | N, $K_2O$, $P_2O_5$, Lime | 5600 | 9000 | 6090 | 4630 | 4190 | 875 | 2625 | 1720 | 4380 | 5800 | 120605 |
| 20 | Manure, Lime | 6800 | 10400 | 6240 | 5010 | 4600 | 1250 | 6000 | 1080 | 5420 | 7400 | ~~210000~~ 152400 |
| 21 | No Fertilizer | 755 | 1305 | 1130 | 1500 | 2900 | 220 | 680 | 350 | 710 | 100 | 38600 |
| 22 | Lime | 535 | 1240 | 1100 | 2470 | 3080 | 250 | 650 | 580 | 1270 | 750 | 36615 |
| 23 | Ash of Manure, N | 490 | 1120 | 890 | 3550 | 4620 | 530 | 1170 | 1490 | 3060 | 2100 | 69270 |
| 24 | No Fertilizer | 535 | 1180 | 900 | 1330 | 1400 | 280 | 420 | *1190 | *3010 | *2660 | 43075 |
| 25 | Manure | 7800 | 9000 | 6640 | 4800 | 4400 | 1040 | 3760 | 1380 | 3420 | 5650 | 139670 |
| 26 | N, $K_2O$, $P_2O_5$ | 4700 | 8700 | 6090 | 4890 | 4450 | 800 | 1800 | 1590 | 3460 | 3250 | 117910 |
| 27 | No Fertilizer | 505 | 1275 | 850 | 1550 | 2900 | 250 | 400 | 370 | 780 | 230 | 42170 |
| 28 | $P_2O_5$, $K_2O$ | 1640 | 3475 | 2280 | 3170 | 4020 | 620 | 1130 | 1230 | 2520 | 1440 | 76995 |
| 29 | N, $K_2O$ | 2125 | 3880 | 2390 | 2050 | 2300 | 380 | 820 | 560 | 890 | 360 | 52215 |
| 30 | No Fertilizer | 705 | 1375 | 930 | 1900 | 1990 | 290 | 710 | 370 | 780 | 230 | 39480 |
| 31 | N, $P_2O_5$ | 4500 | 7300 | 4320 | 4080 | 4200 | 790 | 1410 | 1500 | 2450 | 2590 | 95940 |
| 32 | $K_2O$ | 430 | 1285 | 850 | 2330 | 2400 | 330 | 570 | 380 | 820 | 260 | 41565 |
| 33 | No Fertilizer | 305 | 1260 | 570 | 1900 | 1920 | 300 | 550 | 330 | 770 | 230 | 36845 |
| 34 | $P_2O_5$ | 845 | 3410 | 2290 | 2100 | 2050 | 750 | 1250 | 560 | 990 | 1030 | 63415 |
| 35 | N | 720 | 2885 | 1740 | 1400 | 1380 | 330 | 470 | 340 | 760 | 160 | 41195 |

*Abnormal yields due to an accidental application of manure which was subsequently removed with a rake.

## INCREASE IN YIELD DUE TO FERTILIZER.

| Plot | FERTILIZER | 1900 RYE Grain bu. | 1900 RYE Straw lbs. | 1901 WHEAT Grain bu. | 1901 WHEAT Straw lbs. | 1902 CLOVER Hay lbs. | 1903 CORN Grain bu. | 1903 CORN Stover lbs. | 1904 COW PEAS Hay lbs. | 1905 CORN Ensilage lbs. | 1906 POTATOES Tubers bu. | 1907 RYE Grain bu. | 1907 RYE Straw lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | N, $K_2O$, $P_2O_5$, Lime | 14.73 | 1153 | 9.45 | 2078 | 4330 | 61.43 | 3180 | 5080 | 16620 | 60.00 | 18.32 | 2718 |
| 20 | Manure, Lime | 5.84 | 391 | 12.37 | 2878 | 6480 | 82.86 | 5730 | 4880 | 23620 | 175.67 | 35.64 | 4548 |
| 22 | Lime | -3.11 | -558 | -1.47 | -192 | -870 | -4.00 | -420 | -670 | -1280 | -16.68 | -.25 | 18 |
| 23 | Ash of Manure, N | 15.07 | 1474 | 13.04 | 1638 | 5530 | 35.86 | 2180 | 880 | 4220 | -.33 | .46 | -32 |
| 25 | Manure | 11.82 | 1216 | 13.70 | 2898 | 7180 | 47.57 | 2880 | 4230 | 23720 | 146.33 | 31.00 | 4108 |
| 26 | N, $K_2O$, $P_2O_5$ | 21.64 | 1946 | 10.87 | 2268 | 4880 | 53.14 | 3380 | 4430 | 17920 | 75.17 | 18.32 | 2218 |
| 28 | $P_2O_5$, $K_2O$ | 2.86 | 368 | 7.53 | 1668 | 3130 | 46.57 | 2580 | 2530 | 5020 | 64.00 | 12.61 | 1538 |
| 29 | N, $K_2O$ | 13.02 | 1189 | -.30 | 138 | -370 | -5.71 | -320 | 430 | 3020 | 16.67 | -.07 | -52 |
| 31 | N, $P_2O_5$ | 18.14 | 1782 | 7.53 | 1668 | 5530 | 50.00 | 3380 | 3280 | 7820 | 21.83 | 15.82 | 1958 |
| 32 | $K_2O$ | 2.70 | 307 | -1.13 | -12 | 130 | 1.43 | 130 | 80 | 720 | 1.83 | -.07 | 48 |
| 34 | $P_2O_5$ | 1.95 | 439 | 4.87 | 928 | 3030 | 38.14 | 2130 | 1780 | 3020 | 21.33 | 11.18 | 1618 |
| 35 | N | 11.84 | 1345 | -2.80 | 88 | -230 | -8.14 | -320 | 630 | -880 | -4.50 | 1.18 | -22 |
| Average Yield of Check Plots | | 22.32 | 2371 | 18.30 | 1682 | 2370 | 27.14 | 3620 | 1870 | 11080 | 42.00 | 2.57 | 312 |

## INCREASE IN YIELD DUE TO FERTILIZERS (Continued

| Plot | FERTILIZER | 1909 TIMOTHY & CLOVER Hay lbs. | 1910 TIMOTHY Hay lbs. | 1911 TIMOTHY Hay lbs. | 1912 CORN Grain bu. | 1912 CORN Stover lbs. | 1913 OATS Grain bu. | 1913 OATS Straw lbs. | 1914 WHEAT Grain bu. | 1914 WHEAT Straw lbs. | 1915 CLOVER Hay lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | N, $K_2O$, $P_2O_5$, Lime | 5039 | 7721 | 5214 | 42.77 | 1968 | 18.97 | 2073 | 22.75 | 3620 | 5602 |
| 20 | Manure, Lime | 6239 | 9121 | 5364 | 48.20 | 2378 | 30.69 | 5448 | 12.08 | 4660 | 7202 |
| 22 | Lime | -26 | -39 | 224 | 11.91 | 858 | -.56 | 98 | 3.75 | 510 | 552 |
| 23 | Ash of Manure, N | -71 | -159 | 14 | 27.34 | 2398 | 8.19 | 618 | 18.92 | 2250 | 1902 |
| 25 | Manure | 7239 | 7721 | 5764 | 45.20 | 2178 | 24.13 | 3208 | 17.08 | 2660 | 5462 |
| 26 | N, $K_2O$, $P_2O_5$ | 4139 | 7421 | 5214 | 46.49 | 2228 | 16.63 | 1248 | 20.58 | 2700 | 3062 |
| 28 | $P_2O_5$, $K_2O$ | 1079 | 2196 | 1404 | 21.91 | 1798 | 11.00 | 578 | 14.58 | 1760 | 1242 |
| 29 | N, $K_2O$ | 1564 | 2601 | 1514 | 5.91 | 78 | 3.50 | 268 | 3.42 | 130 | 162 |
| 31 | N, $P_2O_5$ | 3939 | 6021 | 3444 | 34.91 | 1978 | 16.31 | 358 | 19.08 | 1690 | 2392 |
| 32 | $K_2O$ | -131 | 6 | -26 | 9.91 | 178 | 1.94 | 18 | .42 | 60 | 62 |
| 34 | $P_2O_5$ | 284 | 2131 | 1414 | 6.63 | -172 | 15.06 | 698 | 3.42 | 230 | 832 |
| 35 | N | 159 | 1606 | 864 | -3.37 | -842 | 1.94 | -82 | -.25 | 0 | -38 |
| Average Yield of Check Plots ..... | | 561 | 1279 | 876 | 23.37 | 2222 | 8.38 | 552 | 5.92 | 760 | 198 |

## VALUE OF INCREASE PER ACRE DUE TO FERTILIZER.

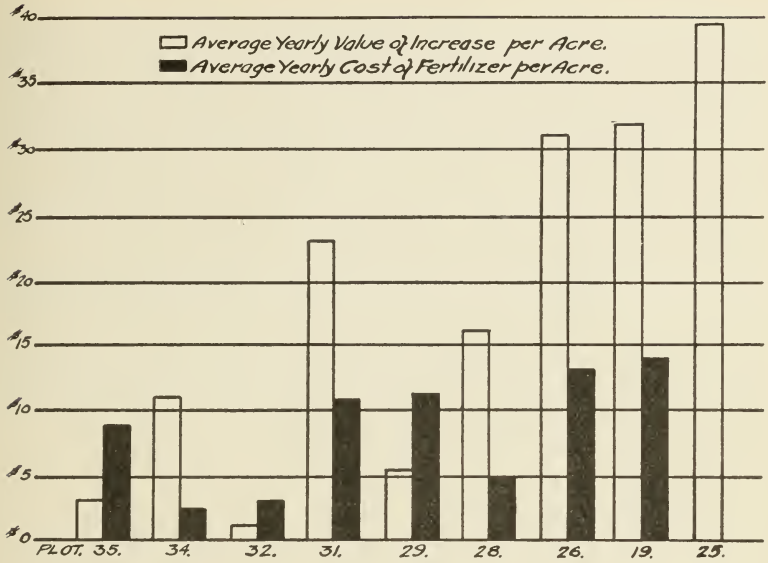
| Plot | FERTILIZER | 1900 RYE | 1901 WHEAT | 1902 HAY | 1903 CORN | 1904 COW PEAS | 1905 CORN | 1906 POTATOES | 1907 RYE |
|---|---|---|---|---|---|---|---|---|---|
| 19 | N, $K_2O$, $P_2O_5$, Lime | $13.92 | $14.18 | $30.31 | $47.88 | $35.56 | $33.24 | $42.00 | $20.54 |
| 20 | Manure, Lime | 5.36 | 18.95 | 45.36 | 68.30 | 34.16 | 47.24 | 122.97 | 38.10 |
| 22 | Lime | -3.73 | -1.88 | -6.09 | -3.65 | -4.69 | -2.56 | -11.67 | -.14 |
| 23 | Ash of Manure, N | 14.99 | 16.48 | 38.71 | 28.76 | 6.16 | 8.44 | -.23 | .27 |
| 25 | Manure | 11.91 | 20.27 | 50.26 | 38.12 | 29.61 | 47.44 | 102.43 | 33.52 |
| 26 | N, $K_2O$, $P_2O_5$ | 21.10 | 16.00 | 34.16 | 42.99 | 31.01 | 35.84 | 52.62 | 19.29 |
| 28 | $P_2O_5$, $K_2O$ | 3.06 | 11.32 | 21.91 | 36.72 | 17.71 | 10.04 | 44.80 | 13.31 |
| 29 | N, $K_2O$ | 12.74 | .06 | -2.59 | -4.51 | 3.01 | 7.84 | 11.67 | -.18 |
| 31 | N, $P_2O_5$ | 18.07 | 11.32 | 38.71 | 40.95 | 22.96 | 15.64 | 15.28 | 16.77 |
| 32 | $K_2O$ | 2.79 | -1.10 | .91 | 1.26 | .56 | 1.44 | 1.28 | .07 |
| 34 | $P_2O_5$ | 2.56 | 6.95 | 21.21 | 30.12 | 12.46 | 6.04 | 14.93 | 12.44 |
| 35 | N | 12.24 | -2.44 | -1.61 | -6.09 | 4.41 | -1.76 | -3.15 | .83 |
| Average Yield and Value of Yield of Check Plots..... | | $22.68 | $21.60 | $16.59 | $26.69 | $13.09 | $22.16 | $29.40 | $2.71 |

## VALUE OF INCREASE PER ACRE DUE TO FERTILIZER (Continued)

| Plot | FERTILIZER | 1909 TIMOTHY & CLOVER | 1910 TIMOTHY | 1911 TIMOTHY | 1912 CORN | 1913 OATS | 1914 WHEAT | 1915 CLOVER |
|---|---|---|---|---|---|---|---|---|
| 19 | N, $K_2O$, $P_2O_5$, Lime | $35.27 | $54.05 | $36.50 | $32.71 | $13.72 | $30.66 | $39 21 |
| 20 | Manure, Lime | 43.67 | 63.85 | 37.55 | 37.28 | 27.43 | 23.13 | 50.41 |
| 22 | Lime | -.18 | .27 | 1.57 | 9.89 | .00 | 4.84 | 3.80 |
| 23 | Ash of Manure, N | -.50 | 1.11 | .10 | 23.77 | 5.24 | 23.60 | 13.31 |
| 25 | Manure | 50.67 | 54.05 | 40.35 | 34.83 | 18.88 | 22.88 | 38.23 |
| 26 | N, $K_2O$, $P_2O_5$ | 28.97 | 51.95 | 36.50 | 35.79 | 10.60 | 26.30 | 21 43 |
| 28 | $P_2O_5$, $K_2O$ | 7.55 | 15.37 | 9.83 | 18.74 | 6.40 | 18.25 | 8.69 |
| 29 | N, $K_2O$ | 10.95 | 18.21 | 10.60 | 4.04 | 2.25 | 3.58 | 1.12 |
| 31 | N, $P_2O_5$ | 27.57 | 42.15 | 24.11 | 27.64 | 9.49 | 22.36 | 16.74 |
| 32 | $K_2O$ | -.92 | .04 | -.18 | 6.89 | .92 | .55 | .43 |
| 34 | $P_2O_5$ | 1.99 | 14.92 | 9.90 | 3.88 | 8.53 | 3.83 | 5.82 |
| 35 | N | 1.11 | 11.24 | 6.05 | -4.30 | .66 | -.24 | -.27 |
| Average Yield and Value of Yield of Check Plots..... | | $3.93 | $8.95 | $6.13 | $20.75 | $5.15 | $7.52 | $1.39 |

## AVERAGE YEARLY VALUE PER ACRE OF INCREASE.

| Plot | FERTILIZER | First Five Years | Second Five Years | Third Five Years | 15 Year Average | Yearly Cost of Fertilizer | Value of Increase Less Cost of Fertilizer |
|---|---|---|---|---|---|---|---|
| 19 | N, $K_2O$, $P_2O_5$, Lime | $28.37 | $37.02 | $30.56 | $31.98 | $14.10 | $17.88 |
| 20 | Manure, Lime | 34.43 | 63.17 | 35.16 | 44.25 | ? | ? |
| 22 | Lime | -4.01 | -2.86 | 4.03 | -.9[illegible] | .92 | -1.87 |
| 23 | Ash of Manure, N | 21.02 | 1.82 | 13.20 | 12.01 | ? | ? |
| 25 | Manure | 30.03 | 57.62 | 31 03 | 39 56 | ? | ? |
| 26 | N, $K_2O$, $P_2O_5$ | 29.05 | 37.73 | 26.12 | 30.97 | 13.35 | 17.62 |
| 28 | $P_2O_5$, $K_2O$ | 18.14 | 18.21 | 12.38 | 16.24 | 4.95 | 11.29 |
| 29 | N, $K_2O$ | 1.74 | 9.70 | 4.32 | 5.25 | 11.11 | -5.86 |
| 31 | N, $P_2O_5$ | 26.40 | 23.48 | 20.07 | 23.32 | 10.64 | 12.68 |
| 32 | $K_2O$ | .88 | 33 | 1.72 | .99 | 2.71 | -1.72 |
| 34 | $P_2O_5$ | 14.66 | 10.06 | 6.33 | 10.37 | 2.24 | 8.13 |
| 35 | N | 6.51 | 1.65 | .38 | 2.85 | 8.40 | -5.55 |
| Axerage Yearly Value per Acre of Produce of Check Plots ..... | | $20.13 | $13.43 | $8.19 | $13.92 | | |




35 Nitrate of Soda
34 Acid Phosphate
32 Sulphate of Potash
31 Nitrate of Soda and Acid Phosphate
29 Nitrate of Soda and Sulphate of Potash
28 Acid Phosphate and Sulphate of Potash
26 Nitrate of Soda, Acid Phosphate and Sulphate of Potash
19 Nitrate of Soda, Acid Phosphate, Sulphate of Potash and Lime
25 *Manure

*No estimate put on the cost of manure

The calculations of the value of the increase were made by using the average farm values of the products in West Virginia since 1900 as obtained from the Year Book of the U. S. Department of Agriculture, which were as follows: corn, $.65; wheat, $.95; oats, $.45; rye, $.75; hay $14.00; ensilage, $4.00; stover, $5.00; straw, $5.00. The following values were placed on the fertilizers and do not take into consideration the cost of delivering from the railway station to the farm and making the application: acid phosphate, $16.00; nitrate of soda, $60.00; sulphate of potash, $50.00; lime, $5.00. The fertilizer applications per acre during the experiment have totaled 4,200 pounds of nitrate of soda, 4,200 pounds of acid phosphte, 1,625 pounds of sulphate of potash, 4,500‡ pounds of lime and 190* tons of manure.

‡ 5,500 pounds lime on plot 22.
* 210 tons manure on plot 20.

## CONCLUSIONS.

A study of the results from the experimental use of fertilizers at the West Virginia Agricultural Experiment Station justifies the following conclusions:

1. Manure is a material of sufficient fertilizing value to entitle it to more consideration than many farmers give it. Even when applied in such liberal quantities as it has been in these experiments, every ton of manure has produced an increase valued at $3.12.

2. The importance of acid phosphate as a crop producer is such that one need not hesitate to buy and apply it in liberal quantities.

3. If we subtract the value of the increase produced by nitrate of soda alone, from the value of the increase produced by acid phosphate and nitrate of soda in combination, it appears that for every dollar invested in acid phosphate $9.14 worth of increase crop was produced. This indicates that if more legumes had been grown on the soil and the amount of nitrogen in the soil had been increased thereby we could expect a greater return from the use of acid phosphate on the plot receiving acid phosphate alone.

4. The return per dollar invested in acid phosphate is decreasing as the years go by, where acid prosphate is used alone. This is probably because of the fact that nitrogen is becoming a seriously limiting factor. If legumes had appeared oftener in the rotation, this decrease would probably not have taken place.

5. Under the system of farming practiced in this experiment, complete fertilizers would be more desirable than acid phosphate alone. But this is not an ideal farming system for the economical maintenance of fertility. No attempt has been made to keep up the supply of organic matter, no manure has been applied to the fertilizer plots and only one leguminous crop has been grown every five years.

6. The results indicate that the complete fertilizer would have been less profitable if some catch crop had been plowed under and legumes had played a more prominent part in the rotation.

7. In determining which fertilizing material or mixture of fertilizing materials is the most profitable several things must be taken into consideration. In applying the complete fertilizer we may secure a larger yield but we also have more crop to handle, more fertilizer to haul to the farm and apply, more money invested in fertilizer and consequently a heavier risk to run, against which we must be insured. The complete fertilizer in these experiments gave three times as much increase as acid phosphate alone. But there was two and one half times as much fertilizer to handle, twice as much crop to take care of and six times as much money invested in fertilizer.

April, 1916 Bulletin 156

West Virginia University
Agricultural Experiment Station
MORGANTOWN, W. VA.

DEPARTMENT OF HORTICULTURE

# A SECOND REPORT
ON THE
# UNIVERSITY FARM GARDEN

Products of University Farm Garden Exhibited October 12th.

BY
ARTHUR L. DACY

The Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon writen application. Address Director of Agricultural Experiment Station, Morgantown, W. Va.

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*In co-operation with U. S. Department of Agriculture.
†In co-operation with the University of Chicago.

# A Second Report on the University Farm Garden

By ARTHUR L. DACY.

In Circular 17* of this Station, the writer presented a report of the results secured in the University Farm Garden in 1913 and 1914. Another year's records being available it is deemed advisable to publish them at this time together with an average of the results obtained during the past three years.

The University Farm Garden as cultivated in 1915 occupied four and seven-tenths acres of land. Of this area, three acres in one block containing Plots 1 to 30 inclusive had been in garden vegetables in 1913 and 1914; six-tenths of an acre containing Plots 31 to 36 inclusive was in potatoes in 1914 and in sod in 1913; and one and one-tenth acres containing Plots 37 to 47 inclusive was a two-year-old strawberry bed which became available about the 4th of July.

The work was carried on in much the same way as in 1914, the garden being divided into tenth-acre plots, two adjoining plots, or one-fifth of an acre in some cases being planted to the same vegetable. As far as possible a companion or succession cropping plan, or both, was tried. With the exception of about $125.00 worth of carrots, parsnips, turnips, spinach and kale which was shipped to commission houses in Fairmont, Clarksburg and Grafton, all of the products of the garden were sold at wholesale to storekeepers in Morgantown. Accurate records were kept of the sales of each vegetable and of each plot so that the returns from both could be easily computed on an acre basis.

The season of 1915 was on the whole favorable for plant growth. Rainfall was abundant and very well distributed throughout the season. The temperature during the last week in May was abnormally low, and in consequence pole lima beans, peppers and eggplants suffered somewhat of a check.

The following table presents a condensed record of the 1915 garden from the standpoint of the different vegetables grown, giving the name of the variety, location, area planted, date of planting, date of first and last sale, the approximate yield, the approximate price at which it sold and the estimated returns per acre for each crop.†

*Circular 17—The University Farm Garden—A. L. Dacy, April, 1915.
†The actual sales from each crop are given in Column 4 of Table II.

TABLE I.—*A Detailed Record of Crops Grown in 1915.*

| Name and Variety of Vegetable | No. of Plot | Area Planted (Acres) | Date of Planting | Date of First Sale | Date of Last Sale | Approximate Yield | Approximate Average Price | Estimated Gross Returns per Acre |
|---|---|---|---|---|---|---|---|---|
| **BEANS—String** | | | | | | | | |
| Stringless Green-pod | 18 | .053 | 4-16 | 6-26 | 7-6 | 3.5 bu. | $1.18 per bu. | $ 78.30 |
| S. G. Pod* & Round Pod Kidney Wax | 21 | .1 | 5-3 | 7-6 | 7-29 | 17. " | .86 " " | 145.70 |
| " " " " " " " | 29 | .042 | 6-8 | 7-29 | 8-10 | 8.5 " | .71 " " | 143.57 |
| " " " " " " " | 3 | .04 | 6-29 | 8-19 | 8-31 | 9.5 " | .69 " " | 165.00 |
| Refugee or 1000 to 1 | 39 | .1 | 7-17 | 9-18 | 10-9 | 24.6 " | .88 " " | 217.80 |
| " " " | 7 & 8 | .2 | 7-27 | 9-22 | 10-11 | 27.7 " | 1.01 " " | 140.00 |
| Giant Stringless Green Pod | 17 | .1 | 8-6 | 10-7 | 10-7 | 5.2 " | 1.25 " " | 65.50 |
| " " " " | 20 | .... | 8-7 | 10-9 | 10-9 | 3. " | 1.25 " " | ..... |
| **BEANS—Bush Lima** | | | | | | | | |
| Fordhook Bush Lima | 13 | .1 | 5-15-18 | 8-14 | 10-12 | 19. " | 1.45 " " | 275.30 |
| **BEANS—Pole Lima** | | | | | | | | |
| S. S. Large Flat Pole† | 25 | .1 | 5-18, 6-16 | 8-21 | 10-7 | 15.2 " | 1.23 " " | 187.90 |
| **BEETS** | | | | | | | | |
| Early Model and Detroit | 17 | .1 | 4-9 | 6-17 | 8-7 | 182 dz. bun. | .30 dz. bun. | |
| | | | | | | 8.75 bu. | .60 per bu. | 603.00 |
| Crosby's Egyptian and Columbia | 19 | .1 | 6-19 | 8-17 | 10-14 | 27 dz. bun. | .21 dz. bun. | |
| | | | | | | 10 bu. | .50 per bu. | 105.80 |
| **CABBAGE** | | | | | | | | |
| Early J. Wakefield, Charleston Wakefield and Copenhagen Market | 7 & 8 | .2 | 4-8 | 6-29 | 7-20 | 2554 lbs. | .02 per lb. | 249.15 |
| Succession | 32 | .1 | 6-23 | 8-14 | 10-9 | 2290 " | .01 " " | 228.00 |
| Flat Dutch and Danish Ball Head | 45 | .1 | 7-9 | 10-26 | 11-26 | 1309 " | .01 " " | 143.30 |
| " " " " " " | 40 | .1 | 7-15 | 11-9 | 11-30 | 590 " | .008 " " | 47.80 |

*In each case after the first appearance of the name of a variety, qualifying adjectives are abbreviated.

†S. S. appearing before a variety signifies Stokes Standard. The seeds planted in the garden (with few exceptions) were purchased from Stokes Seed Farms Co., Moorestown, N. J. and W. Atlee Burpee, Philadelphia, Pa.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **CARROTS** | | | | | | | | |
| Danvers ½ Long, Oxheart and ½ Long Rubicon | 10 | .1 | 4-7 | 6-26 | 10-5 | 66 dz. bun. | .25 dz. bun. | |
| | | | | | | 10.5 bu. | .50 per bu. | 220.10 |
| Danvers ½ Long | 28 | .1 | 5-4 | 9-23 | 11-30 | 15 bbls. | 1.50 " bbl. | |
| | | | | | | 24.5 bu | .75 " bu. | 410.20 |
| **CAULIFLOWER** | | | | | | | | |
| Burpee's Best Early | 20 | .1 | 4-10 | 6-15 | 7-1 | 17 dz. | .88 " dz. | 150.20 |
| " " " | 36 | .085 | 7-2 | 9-11 | 11-13 | 50 " | 1.135 " " | 667.76 |
| **CORN—Sweet** | | | | | | | | |
| Extra Early Adams | 4 | .1 | 4-5 | 7-20 | 7-31 | 71.5 dz. | .30 " " | 214.00 |
| " " " | 4 | .054 | 4-14 | 7-31 | 8-14 | 29.3 " | .26 " " | 140.74 |
| E. E. Adams and Golden Bantam | 2 | .1 | 4-15-27 | 7-20 | 8-14 | 50.5 " | .189 " " | 94.80 |
| Early Mayflower, Early Fordhook, Kendel's Early Giant, S. S. Doubled Barreled Best, Seymour's Sweet Orange and Country Gentleman | 26 & 27 | .2 | 5-4 | 7-27 | 9-2 | 164.0 " | .102 " " | 83.90 |
| S. S. Double Barreled Best, Country Gentleman and White Evergreen | 33 & 34 | .2 | 6-4 | 8-31 | 9-15 | 104.3 " | .114 " " | 59.95 |
| White Evergreen | 20 | .1 | 7-5 | ..... | ..... | No crop | ..... | ..... |
| Early Fordhook and K. Early Giant | 37 & 38 | .2 | 7-13 | 10-7 | 10-7 | 28.5 dz. | .137 " " | 19.50 |
| **CUCUMBERS** | | | | | | | | |
| S. S. White Spine | 18 | .1 | 6-6-8 | 7-31 | 9-23 | 128.5 " | .187 " " | 240.20 |
| **EGGPLANTS** | | | | | | | | |
| Black Beauty | 14 | .1 | 4-29 | 8-7 | 10-12 | 55.5 " | .657 " " | 365.00 |
| **KALE** | | | | | | | | |
| Green Curled Scotch | 46 & 47 | .1 | 7-17-24 | 9-21 | 10-20 | 30 bu. | .34 " bu. | |
| | | | | | | 21 bbls. | .82 " bbl. | 268.00 |
| " " " | 26 | .05 | 8-7 | 10-18 | 11-2 | 17 bu. | .40 " bu. | |
| | | | | | | 9 bbls. | .75 " bbl. | 268.00 |
| " " " | 29 | .05 | 8-19 | 11-3 | 11-30 | 7 bu. | .40 " bu. | |
| | | | | | | 14 bbls. | .75 " bbl. | 266.00 |

TABLE I.—(*Continued*).

| Name and Variety of Vegetable | No. of Plot | Area Planted (Acres) | Date of Planting | Date of First Sale | Date of Last Sale | Approximate Yield | Approximate Average Price | Estimated Gross Returns per Acre |
|---|---|---|---|---|---|---|---|---|
| **KOHLRABI** | | | | | | | | |
| Early White Vienna | 2 | .... | 5-4 | 7-1 | 7-22 | 10.2 dz. bun. | .25 dz. bun. | ..... |
| **LETTUCE—Plants** | | | | | | | | |
| Grand Rapids | 7 & 8 | .174 | 4-9-15 | 5-22 | 5-29 | 160 lbs. | .09 per lb. | 85.06 |
| Black Seeded Simpson | 11 & 12 | .12 | 5-15-20 | 6-29 | 7-8 | 310 " | .02 " " | 53.66 |
| " " " | 1 | .... | ..... | 10-11 | 10-11 | 30 " | .065 " " | ..... |
| **LETTUCE—Seed** | | | | | | | | |
| Black Seeded Simpson | 14 | .1 | 4-8 | 6-3 | 6-26 | 297 " | .054 " " | 161.80 |
| " " " | 5 & 6 | .09 | 7-10 | 9-14 | 9-23 | 390 " | .04 " " | 173.33 |
| **ONIONS—From Sets** | | | | | | | | |
| Egyptian or Perennial Tree | 1 | .02 | 1914 | 5-4 | 5-22 | 61. dz. bun. | .237 per dz. bun. | 724.50 |
| White Bottom Sets | 29 | .033 | 1914 | 5-27 | 6-10 | 11.7 " " | .221 per dz. bun. | ..... |
| " " " | 3 | .042 | 3-15 | 5-29 | 6-19 | 66.7 " " | .206 per dz. bun. | 327.38 |
| **ONIONS—From Seed** | | | | | | | | |
| Prizetaker, Yellow Globe Danvers, Early Red, Australian Brown | 16 | .1 | 4-8 | 7-10 | 10-4 | 44 " " | .25 dz. bun. | |
| | | | | | | 31.5 bu. | .94 per bu. | 407.60 |
| **PARSNIPS** | | | | | | | | |
| Hollow Crown | 9 | .1 | 4-9 | 9-30 | 10-28 | 28 bu. | .75 " bu. | |
| " " | | | | | | 4 bbls. | 1.75 " bbl. | 281.30 |
| | 15 | .1 | 4-10 | 10-25 | 11-30 | 16 bu. | .75 " bu. | |
| | | | | | | 15 bbls. | 1.75 " bbl. | 382.50 |
| **PEAS** | | | | | | | | |
| Prolific Extra Early, Prolific Early Market, Record Extra Early, Extra Early Pilot, Little Marvel | 5 & 6 | .2 | 4-5 | 6-10 | 6-26 | 27 bu. | 1.12 " bu. | 151.75 |
| Burpee's Best Extra Early, Blue Bantam and Harvester | 1 | .058 | 4-6-27 | 6-29 | 7-10 | 9 " | 1.11 " " | 172.93 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PEPPERS** | | | | | | | | |
| Ruby King, Neapolitan, Ruby Giant, Chinese Giant | 24 | .1 | 5-15 | 7-15 | 10-14 | 234 dz.<br>29.5 bu.<br>4. bbls. | .08 per dz<br>.51 " bu.<br>1.00 " bbl. | 382.40 |
| **POTATOES—Irish** | | | | | | | | |
| Irish Cobbler | 22 & 23 | .2 | 4-18 | 8-5 | ..... | 40. bu. | .50 " bu. | 101.25 |
| " " | 43 & 44 | .2 | 7-10-13 | 10-19 | 11-30 | 25.7 " | .52 " " | 67.70 |
| **PUMPKINS** | | | | | | | | |
| S. S. Pie | 4 | .1 | 6-9 | 10-28 | 12-28 | 225 lbs. | .01 " lb. | 22.50 |
| **RADISHES** | | | | | | | | |
| Scarlet Globe and Rapid Red | 9 | .... | 4-9 | 5-18 | 5-18 | 7. dz. bun. | .15 } per | ..... |
| " " " " " | 12 | .... | 4-8 | 5-18 | 5-24 | 9.5 " " | .188 } dz. | ..... |
| " " " " " | 3 | .02 | 8-23 | 9-30 | 10-23 | 29.5 " " | .167 } bun. | 245.50 |
| **SPINACH** | | | | | | | | |
| S. S. Long Season | 4 | .1 | 4-5 | 6-3 | 6-4 | 10.5 bu. | .65 per bu. | 68.00 |
| Norfolk Savoy Leaved | 1 | .039 | 4-6 | 5-29 | 6-1 | 1 bbl. | 1.75 " bbl. | |
| | | | | | | 10.3 bu. | .75 " bu. | 243.59 |
| " " " | 5 & 6 | .2 | 4-6 | 5-22 | 5-26 | 2 bbls. | 2.00 " bbl. | |
| | | | | | | 37.2 bu. | .75 " bu. | 160.25 |
| " " " | 11 | .1 | 4-8 | 6-5 | 6-5 | 8.5 " | .576 " " | 49.00 |
| Victoria | 19 | .1 | 4-16 | 6-8 | 6-12 | 1 bbl. | 1.50 " bbl. | |
| | | | | | | 17 bu. | .69 " bu. | 132.50 |
| Norfolk Savoy Leaved | 18 | .1 | 5-3 | 6-15 | 6-17 | 6 " | .483 " " | 29.00 |
| " " " | 30 | .1 | 5-4 | 6-12 | 6-22 | 1 bbl. | 1.50 " bbl. | |
| | | | | | | 2 bu. | .45 " bu. | 24.00 |
| " " " | 5 & 6 | .04 | 7-12-19 | 8-21 | 9-4 | 13 " | .684 " " | 222.50 |
| " " " | 21 | .08 | 8-3 | 9-13 | 9-28 | 2 bbls. | 1.25 " bbl. | |
| | | | | | | 25 bu. | .546 " bu | 201.87 |
| " " " | 1 | .029 | 8-19 | 10-5 | 10-22 | 1 bbl. | 1.50 " bbl. | |
| | | | | | | 18 bu. | .70 " bu. | 465.51 |
| " " " | 2 | .1 | 8-23 | 10-13 | 10-30 | 9 bbls. | 1.25 " bbl. | |
| | | | | | | 36.5 bu. | .735 " bu. | 381.00 |

TABLE I.—(*Continued*).

| Name and Variety of Vegetable | No. of Plot | Area Planted (Acres) | Date of Planting | Date of First Sale | Date of Last Sale | Approximate Yield | Approximate Average Price | Estimated Gross Returns per Acre |
|---|---|---|---|---|---|---|---|---|
| **SPINACH**—Continued. | | | | | | | | |
| Norfolk Savoy Leaved | 3 | .02 | 8-23 | 11-1 | 11-1 | 2 bbls.<br>2 bu. | 1.25 per bbl.<br>.75 " bu. | 200.00 |
| " " " | 22 & 23 | .2 | 9-2 | 11-1 | 12-24 | 7 bbls.<br>49 bu. | 1.25 " bbl.<br>.75 " bu. | 227.50 |
| **SQUASH** | | | | | | | | |
| White Bush, Fordhook, Delicious, Hubbard | 35 | .1 | 6-10-17 | 8-12 | 11-2 | 18 dz.<br>231 lbs.<br>1 bbl. | .32 " dz.<br>.016 " lb.<br>1.25 " bbl. | 106.90 |
| **TOMATOES** | | | | | | | | |
| Earliana, Chalk's Jewel, Bonny Best, John Baer, I X L, Greater Baltimore, My Maryland, and Sunrise | 11 & 12 | .2 | 5-14 | 7-1 | 9-18 | 4576 lbs. | .024 " lb. | 564.40 |
| Stone | 31 | .1 | 6-1 | 8-21 | 10-7 | 2158 " | .013 " " | 284.40 |
| Bonny Best | 41 & 42 | .2 | 7-13 | 10-9 | 11-6 | 600 " | .018 " " | 56.55 |
| **TURNIPS** | | | | | | | | |
| Purple Top Strap Leaf and White Egg | 46 & 47 | .1 | 7-24 | 9-7 | 10-12 | 22.9 dz. bun.<br>3 bu.<br>4 bbls. | .24 " dz.<br>.50 " bu.<br>1.50 " bbl. | 129.80 |

## NOTES ON TABLE I.

A few points of unusual interest regarding the crops grown may be presented briefly as follows, considering them in alphabetical order.

It will be noticed that the most profitable planting of beans was that of July 17th following the two-year-old strawberry bed. The poor showing of the pole lima beans was due to the fact already noted that the latter part of May was wet and cold, making it necessary to replant nearly the whole plot.

The decided difference between the spring and fall crop of cauliflower grown from the same lot of seed is worth emphasizing. This was largely due to the more favorable conditions at heading time afforded by the cool fall weather.

By far the most profitable planting of sweet corn was that of the Extra Early Adams variety on April 5th. While this is not a high quality variety it is of value to the market gardener because of its great hardiness, productiveness and early maturity. Coming as it does so early in the season it always brings a good price.

The variety test in Plots 26 and 27 which follows showed the Double Barreled Best to have been the most productive. This was confirmed by the results in Plots 33 and 34 in

FIG. I.—Plots 7 and 8. Cabbage with Lettuce Between.

which from six rows each of White Evergreen and Country Gentleman, the yield was 34⅙ and 31⅔ doz. respectively, while the five rows of Double Barreled Best produced 37 11-12 doz. In both cases the White Evergreen out-yielded the Country Gentleman. Apparently there was something wrong with the Kendel's Early Giant. It is listed by seedsmen as an early variety and was planted as such. It proved to be decidedly a mid-season sort in this test.

*Variety Test of Sweet Corn—1915.*

| Dates of Harvesting | Variety, Seedsman and Yield | | | | | | |
|---|---|---|---|---|---|---|---|
| | Early Mayflower Stokes (Ears) | Early Fordhook Burpee (Ears) | Seymour's Sweet Orange Burpee (Doz.) | Double Barreled Best Stokes (Doz.) | Kendel's Early Giant Burpee (Doz.) | White Evergreen Burpee (Doz.) | Country Gentleman Burpee (Doz.) |
| July 26 | 5 | | | | | | |
| July 28 | 5 | 9 | | | | | |
| August 4 | 2 | 9 | | | | | |
| August 9 | 10 | 56 | 2⅔ | | | | |
| August 11 | | | 1 11-12 | 1¼ | | | |
| August 13 | | | 2 | 4½ | | | |
| August 16 | | | 3½ | 2¾ | 5 | 3 | |
| August 18 | | | 2 | 3⅚ | 4 | 3½ | |
| August 20 | | | ¾ | 3⅔ | 1⅔ | 5¼ | 4⅚ |
| August 23 | | | | 4¼ | 1⅚ | 3⅔ | 2½ |
| August 25 | | | | 1⅓ | ½ | 1 | 2 |
| August 27 | | | | 2 | | 1 | 1⅙ |
| August 30 | | | | | | 5-12 | 1 |
| September 1 | | | | | | ½ | 1 |
| Total Yield (Doz.) | 1⅚ | 6⅙ | 12⅚ | 23 7-12 | 13 | 18⅓ | 12½ |

The returns from sweet corn were exclusive of the value of the stover which of course is considerable to the farmer as it makes excellent feed for stock if used as soon as the marketable ears are sold.

Of the onions grown from seed in Plot 16 the Prizetaker out-yielded the other varieties.

All of the peas in Plots 5 and 6 having been planted on the same day, some information was afforded as to the relative earliness of the different varieties, which together with some data on the varieties planted in Plot 1, is presented as follows:

*Variety Test of Peas—1915.*

| No. of Rows | Name of Variety | Date Planted | First Picking | Last Picking | Yield (Bu.) |
|---|---|---|---|---|---|
| 5 | Prolific Extra Early | 4-5 | 6-14 | 6-25 | 8.75 |
| 5 | *Prolific Early Market | 4-5 | 6-21 | 6-23 | 4.5 |
| 4 | *Record Extra Early | 4-5 | 6-9 | 6-23 | 6. |
| 4 | *Little Marvell | 4-5 | 6-21 | 6-25 | 5. |
| 4 | Extra Early Pilot | 4-5 | 6-16 | 6-16 | 4. |
| 2 | Best Extra Early | 4-27 | 6-28 | 6-28 | 2. |
| 2 | Blue Bantam | 4-6 | 6-28 | 6-28 | 3. |
| 2 | *Harvester | 4-6 | 7-5 | 7-9 | 3.75 |

*These varieties were purchased from Stokes Seed Farms, Moorestown, N. J. The others were purchased from W. Atlee Burpee & Co. of Philadelphia, Pa.

The Irish Cobbler potatoes planted in Plots 43 and 44 were planted from seed which was obtained from T. W. Wood & Sons of Richmond, Virginia. This firm and others in that part of the country place large quantities of northern grown seed of this variety in cold storage every year for growers who make a practice of planting it in July, using the product for seed the following spring. It should be possible for West Virginia farmers in the southern part of the state and in the lower altitudes elsewhere to follow this same practice to good advantage. In the instance noted a yield of approximately 125 bushels per acre of tubers suitable for seed was secured.

In Plot 12 a careful record was kept of the yield of one row each, of eight varieties of tomatoes, each row being 140 feet long. The following table presents the data of interest:

*Variety Test of Tomatoes—1915.*

| Variety | Date of First Picking | Yield to Aug. 1st | | Yield to Aug. 15th | | Total Yield to Sept. 17th | | Equivalent to Bu. per Acre of Merch. |
|---|---|---|---|---|---|---|---|---|
| | | Merch. Lbs. | Culls Lbs. | Merch. Lbs. | Culls Lbs. | Merch. Lbs. | Culls Lbs. | |
| Earliana[1] | 6-30 | 35 | 9¾ | 191½ | 51 | 472 | 172 | 786.6 |
| I. X. L.[2] | 7-21 | 18¾ | 3½ | 177¼ | 43½ | 384 | 123 | 640. |
| John Baer[2] | 7-26 | 4½ | 2½ | 74 | 35¼ | 281½ | 142¾ | 469.1 |
| Chalk's Jewel[3] | 7-21 | 10¼ | 2½ | 138¼ | 34¾ | 340½ | 151¼ | 567.5 |
| Bonny Best[1] | 7-21 | 7¾ | 1⅜ | 130¾ | 27⅜ | 363¾ | 132⅞ | 606.2 |
| Greater Balt.[2] | 7-28 | 1¾ | ¾ | 24¼ | 17¾ | 291¼ | 98½ | 485.3 |
| My Maryland[2] | 7-26 | 2¼ | ¾ | 35¼ | 11¼ | 273¼ | 71¾ | 455.4 |
| Sunrise[4] | 7-21 | None | 4 | None | 33 | None | 348 | 580.[5] |

[1] Seed bought from Stokes Seed Farms Co., Moorestown, N. J.
[2] Seed furnished by J. Bolgiano & Son, Baltimore, Md.
[3] Seed bought from W. Atlee Burpee & Co., Philadelphia, Pa.
[4] Seed bought from Carter's Tested Seeds, Inc., Boston, Mass.
[5] Culls.

In explanation of the table it should be stated that the plants of these varieties received the same treatment except that the row of Stoke's Earliana was transplanted from four inch pots to the field while the others were from flats in which the plants were set 2 x 2 inches. Carter's Sunrise produced an abundance of smooth, attractive fruit but all too small to be salable in our market.

A market gardener aims to have a constant supply of the different vegetables which he grows at the time when there is a demand for them. This result may be secured by planting at the same time several varieties which mature at different periods (see dates of picking peas and corn on pages 11 and 10), by making successive plantings of the same variety at intervals of from one to two weeks or by a combination of the two methods. An examination of the 5th and 6th columns in Table I shows, for example, that there was a constant supply of string beans from June 26th to August 10th. There was then a break of 9 days to August 19th and another break from August 31st to September 18th after which there was a constant supply until October 9th. Under some circumstances and with some crops these breaks in the supply would have meant a serious loss of trade for the gardener, but in this particular case they came at opportune times for from August 26th until September 16th—the period between the end of the Summer School and the opening day of the fall semester at the University—there are no students in Morgantown. This has a marked effect on the market for green vegetables.

Table II presents in condensed form a record of the 1915 garden from the standpoint of returns from the different plots. It gives the name of the variety, the date of planting, the number of days in which it occupied the plot, the actual receipts from the sale of each vegetable in each plot and the estimated gross returns per acre for each plot.

TABLE II.—*The Detailed Record of Each Plot—1915 Garden.*

| No. of Plot | Crops Planted with Varieties and Dates of Planting | No. of Days Crop Occupied Plot | Actual Receipts from Each Crop | Estimated Returns per Acre for Plot | Remarks |
|---|---|---|---|---|---|
| 5 & 6 | Prolific Extra Early, Record Extra Early, Prolific Early Market, Little Marvel and Extra Early Pilot Peas, 4-5 | 82 | $ 30.35 | | One-fifth acre in plot. 22 rows of peas with spinach between followed by 13 rows G. S. B. Celery and 17 rows of other celery with 8 rows of lettuce and 5 rows of spinach between the celery rows. 11 of the 17 rows of late celery were planted in a bed with plants set one foot by six inches apart. G. S. B. Celery returned $89.00; the late varieties $63.74. See Figs. III and IV. |
| | Norfolk Savoy Leaved Spinach, 4-6 | 57 | 32.05 | | |
| | Golden Self Blanching, Giant Pascal, Winter Queen & Fordhook Emperor Celery, 7-9-12 | 170 | 152.74 | | |
| | Norfolk Spinach, 7-12-19 | 54 | 8.90 | | |
| | Black Seeded Simpson Lettuce, 7-10-12 | 75 | 15.60 | $1,198.20 | |
| 17 | Early Model and Detroit Dark Red Beets, 4-9 | 120 | 60.30 | | All but 8¾ bu. of beets were sold as bunch beets. |
| | Giant Stringless Green Pod Beans, 8-6 | 62 | 6.55 | 668.50 | |
| 11 & 12 | Earliana, I X L, John Baer, Chalk's Jewel, Bonny Best, Greater Baltimore, My Maryland, and Sunrise Tomatoes, 5-14-15 | 127 | 112.88 | | One-fifth acre in plot. 21 rows of tomatoes, with 9 rows of radishes and 10 of spinach between and with one head of lettuce transplanted from Plot 14 between each two tomato plants in 11 of the 21 rows. The tomatoes in Plot 11 were followed by cabbage plants, 10-15, to see if they would live over the winter. |
| | Norfolk Spinach, 4-8 | 58 | 4.90 | | |
| | Rapid Red and Scarlet Globe Radishes, 4-8 | 47 | 1.79 | | |
| | B. S. Simpson Lettuce, 5-15-20 | 54 | 5.34 | 624.55 | |
| 36 | Burpee's Best Early Cauliflower, 7-2 | 134 | 56.76 | | 11 rows of cauliflower and 2 of cabbage. Got a good stand of crimson clover for a cover crop in this plot. |
| | Perfection Drumhead Savoy Cabbage, 7-2 | | .70 | 574.60 | |

TABLE II.—(*Continued*).

| No. of Plot | Crops Planted with Varieties and Dates of Planting | No. of Days Crop Occupied Plot | Actual Receipts from Each Crop | Estimated Returns per Acre for Plot | Remarks |
|---|---|---|---|---|---|
| 14 | Black Beauty Eggplant, 5-29 | 106 | 36.50 | | 9 rows of lettuce seed sown 4-8 between what later were 10 rows of egg plant. Got a good stand of crimson clover on this plot. |
| | B. S. Simpson Lettuce, 4-8 | 79 | 16.80 | 526.80 | |
| 1 | 5 rows, Perennial Tree Onions, 1914 | 140* | 14.49 | | This plot was used as a miscellaneous plot in which were planted some new or uncommon vegetables grown chiefly for illustrative purposes. One plant of lettuce was set between each two of Chinese cabbage. Even though no sales were made of several of the vegetables in this plot it is well up toward the head in gross returns, illustrating the value of keeping the ground busy throughout the season. |
| | 2 rows, Blue Bantam Peas, 4-6, 2 rows, Harvester Peas, 4-6, 2 rows, Burpee's Best Extra Early Peas, 4-27 | 83<br>95<br>62 | 10.03 | | |
| | 3 rows, Norfolk Spinach, 4-6 | 56 | 9.50 | | |
| | 1 row, Swiss Chard, 4-27 | ..... | ..... | | |
| | 1 row, Green Curled Endive, 4-27 | ..... | ..... | | |
| | 1 row, Corn Salad, 4-27 | ..... | ..... | | |
| | 2 rows, Witloof Chicory, 4-27 | ..... | ..... | | |
| | 2 rows, G. C. Endive, 7-27 | 120 | 2.10 | | |
| | 2 rows, Chinese Cabbage, 7-29 | 96 | .45 | | |
| | 1 row, Celeriac, 7-29 | 101 | .25 | | |
| | 1½ rows, Chinese Radish, 8-19 | ..... | ..... | | |
| | 9 rows, N. S. L. Spinach, 8-19 | 64 | 13.50 | | |
| | B. S. Simpson Lettuce | ..... | 2.00 | 523.20 | |
| 2 | Adams Early, Extra Early Adams Corn, 4-15 and Golden Bantam Corn, 4-27 | 121 | 9.48 | | 4 rows of Golden Bantam, 1¼ rows Extra Early Adams and 3¾ rows Adams Early Corn. 4 rows of kohlrabi between corn. All followed by spinach. |
| | Early White Vienna Kohlrabi, 5-4 | 79 | 2.55 | | |
| | N. S. L. Spinach, 8-23 | 68 | 38.10 | 501.30 | |

*Number of days in 1915

| | | | | | |
|---|---|---|---|---|---|
| 7 & 8 | Early Jersey Wakefield, Charleston Wakefield and Copenhagen Market Cabbage, 4-9 | 102 | 49.83 | | One-fifth acre in plot. 9, 11 and 11 rows of cabbage respectively with a head of lettuce between each two heads of cabbage in 27 rows; cabbage followed by beans. See Figs. I and II. |
| | Grand Rapids Lettuce, 4-9-15 | 50 | 14.80 | | |
| | Refugee or 1000 to 1 Beans, 7-27 | 76 | 28.00 | 463.15 | |
| 28 | Danvers ½ Long Carrots, 5-4 | 210 | 41.02 | 410.20 | |
| 16 | Prizetaker, Yellow Globe, Danvers, Early Red and Australian Brown Onions from seed, 4-8 | 179 | 40.76 | 407.60 | 9, 12, 5, and 4 rows of a variety respectively. $11.15 of the $40.76 was received from sales of bunch onions which were thinned out of this plot. |
| 15 | Hollow Crown Parsnips, 4-10 | 233 | 38.25 | 382.50 | A much better stand was secured on this plot than on Plot 9. |
| 24 | Ruby King, Ruby Giant, Chinese Giant, and Neapolitan Peppers, 5-15 | 152 | 38.24 | 382.40 | Got a good stand of crimson clover for a cover crop on this plot. |
| 3 | White Bottom Onion sets, 3-15 | 96 | 13.75 | | 12 rows of onion sets and six rows of corn. Followed former with beans and latter with spinach and radishes. |
| | S. G. Pod and R. P. Kid. Wax Beans, 6-29 | 63 | 6.60 | | |
| | Scarlet Globe Radishes, 8-23 | 61 | 4.91 | | |
| | E. E. Adams Corn, 4-14 | 122 | 7.60 | | |
| | N. S. L. Spinach, 8-23 | 70 | 4.00 | 368.60 | |
| 22 & 23 | Irish Cobbler Potatoes, 4-17-19 | 132 | 20.25 | | One-fifth acre in plot. |
| | N. S. L. Spinach, 9-3 | 112 | 45.50 | 328.75 | |
| 18 | Stringless Green Pod Beans, 4-16 | 81 | 4.15 | | Marked out the plot for 7 rows of cucumbers 4 ft. apart. Planted one row of beans between and one row of spinach 1 ft. on each side of the cucumber row. |
| | N. S. L. Spinach, 5-3 | 45 | 2.90 | | |
| | S. S. White Spine Cucumbers, 6-6-8 | 109 | 24.03 | 310.80 | |
| 21 | S. G. Pod and R. P. Kid. Wax Beans, 5-3 | 87 | 14.57 | | The plants for the celery crop were purchased from a New Jersey firm. They heated so badly in transit that what few were fit to plant did not mature. |
| | N. S. L. Spinach, 8-3 | 56 | 16.15 | | |
| | Giant Pascal Celery, 8-3 | | | 307.20 | |
| 4 | E. E. Adams Corn, 4-5 | 91 | 21.40 | | 11 rows of corn with 10 rows of spinach between. Pumpkins planted in proper spaces in corn. |
| | S. S. Long Season Spinach, 4-5 | 60 | 6.80 | | |
| | S. S. Pie Pumpkins, 6-29 | 141 | 2.25 | 304.50 | |

TABLE II.—(*Continued*).

| No of Plot | Crops Planted with Varieties and Dates of Planting | No. of Days Crop Occupied Plot | Actual Receipts from Each Crop | Estimated Returns per Acre for Plot | Remarks |
|---|---|---|---|---|---|
| 29 | S. G. Pod and Round Pod Kidney Wax Beans, 6-8 | 63 | 6.03 | | 5 and 3 rows respectively of each variety of beans followed by 11 rows of kale. |
| | Dwf. Curled Scotch Kale, 8-19 | 103 | 13.30 | | |
| | Onions from sets, 1914 | 161 | 2.60 | 292.40 | |
| 9 | Hollow Crown Parsnips, 4-9 | 202 | 28.13 | | Radishes were sown with parsnip seed to mark the rows and assist seed in breaking through. |
| | Rapid Red Radishes, 4-9 | 39 | 1.07 | 292.00 | |
| 31 | Stone Tomatoes, 6-1 | 128 | 28.40 | 284.00 | Got a fair stand of crimson clover as a cover crop on this plot. |
| 13 | Fordhook Bush Lima Beans, 5-15-18 | 150 | 27.53 | 275.30 | Got a good stand of crimson clover as a cover crop on this plot. |
| 19 | Victoria Spinach, 4-16 | 57 | 13.25 | | A poor stand of spinach. |
| | Crosby's Egyptian and Columbia Beets, 6-19 | 117 | 10.58 | 238.30 | |
| 32 | Succession Cabbage, 6-23 | 108 | 22.80 | 228.00 | Got a good stand of crimson clover as a cover crop on this plot. |
| 10 | Oxheart, S. S. Rubicon ½ Long & Danvers ½ Long Carrots, 4-7 | 181 | 22.01 | 220.10 | Followed carrots with cabbage plants, 10-15, to see if they would live over the winter. |
| 39 | Refugee or 1000 to 1 Beans, 7-17 | 84 | 21.78 | 217.80 | This planting followed a two-year-old strawberry bed. The most profitable planting of beans in the season. |
| 46 & 47 | Dwarf Curled Scotch Kale, 7-17 and 24 | 95 | 26.80 | | Half of each plot was in kale and half in turnips. One-fifth acre in the combined plots. |
| | Purple Top Strap Leaf Turnips, 7-24 | 80 | 12.98 | 198.90 | |

| | | | | | |
|---|---|---|---|---|---|
| 25 | S. S. Large Flat Pole Lima Beans, 5-18 and 6-16 | 142 | 18.79 | 187.90 | Had to replant nearly the whole plot. Got a good stand of crimson clover for a cover crop on this plot. |
| 20 | B. B. E. Cauliflower, 4-10 | 82 | 15.02 | | The corn did not mature before frost. An earlier maturing variety should have been used. Beans planted in corn rows. |
| | White Evergreen Corn, 7-5 | ..... | ..... | | |
| | Giant S. Green Pod Beans, 8-7 | 63 | 3.75 | 187.70 | |
| 26 & 27 | Early Mayflower, Ea. Fordhook, Kendel's Ea. Giant, S. S. Double Barreled Best, Seymour's Sweet Orange, Country Gentleman and White Evergreen Corn, 5-4 | * | 16.78 | | 3 rows of each variety of corn. The first two varieties were folowed with kale and a fine stand of crimson clover was secured for a cover crop on the balance of the plot. |
| | D. C. S. Kale, 8-7 | 87 | 13.40 | 150.90 | |
| 45 | Flat Dutch and Danish Ballhead Cabbage, 7-9 | 140 | 14.33 | 143.30 | This crop followed a two-year-old strawberry bed. |
| 35 | Mammoth White Bush, Fordhook, Delicious and Hubbard Squash, 6-10-17 | 145 | 10.69 | 106.90 | |
| 43 & 44 | Irish Cobbler Potatoes, 7-10-13 | 101 | 13.54 | 67.70 | Cold storage seed used. |
| 33 & 34 | S. S. D. B. Best, C. Gentleman and White Evergreen Corn, 6-4 | 102 | 11.99 | 59.95 | Got a fine stand of crimson clover for a cover crop in the corn. |
| 41 & 42 | Bonny Best Tomatoes, 7-12-14 | 91 | 11.31 | 56.55 | This crop followed a two-year-old strawberry bed. |
| 40 | Flat Dutch and Danish Ballhead Cabbage, 7-15 | 137 | 4.78 | 47.80 | This crop followed a two-year-old strawberry bed. |
| 30 | Palmetto Asparagus, Spring of 1914 | ..... | .20 | | 1 row of spinach between each 2 rows of asparagus. |
| | N. S. L. Spinach, 5-4 | 49 | 2.40 | 26.00 | |
| 37 & 38 | E. Fordhook and K. E. Giant Corn, 7-13 | 86 | 3.90 | 19.50 | K. E. Giant did not mature before frost. |

*See variety test of corn, page 10, for dates of harvesting of each variety.

## NOTES ON TABLE II.

It will be noticed that every one of the 47 plots in the garden except numbers 15, 16, 28, and 39, affords an illustration of either companion cropping, succession cropping, or improvement cropping by the use of a leguminous cover crop. In several instances two of these plans were used. The examples of each plan will be listed under its appropriate heading.

*1.—Companion Cropping.*

| No. of Plot | Companion Crop | Panted with | Remarks |
|---|---|---|---|
| 1 | Lettuce plants | Chinese Cabbage | A good combination |
| 7 & 8 | " " | Cabbage | " " " |
| 12 | " " | Tomatoes | " " " |
| 5 & 6 | " seed | Celery | " " " |
| 14 | " " | Eggplant | " " " |
| 1,5 & 6 | Spinach | Peas | " " " |
| 5 & 6 | " | Celery | " " " |
| 4 | " | Sweet Corn | " " " |
| 11 | " | Tomatoes | " " " |
| 18 | " | Cucumbers | " " " |
| 30 | " | Asparagus | Not a good combination except the first year. |
| 9 | Radishes | Parsnips | A good combination. |
| 12 | " | Tomatoes | " " " |
| 2 | Kohlrabi | Sweet Corn | Kohlrabi should have been planted earlier. |
| 18 | String Beans | Cucumbers | A good combination. |

FIG. II.—Same Plots as in FIG. I. Beans Following the Cabbage and Lettuce.

*2.—Succession Cropping.*

| No. of Plot | Early Crop | Followed by | Remarks |
|---|---|---|---|
| 1 | Onion sets | Chinese Cabbage | With good results. |
| 3 | " " | String Beans | " " " |
| 1 | Peas | Celeriac, Endive and Winter Radishes | This plan worked out all right but not much sale for these vegetables. |
| 4 & 5 | " | Celery, Lettuce and Spinach | Gave largest gross returns of all. |
| 2 & 3 | Sweet Corn | Spinach | With good results. |
| 3 | " " | Radishes | " " " |
| 26 | " " | Kale | " " " |
| 4 | " " | Pumpkins | With poor results this year. Good results in 1914. |
| 7 & 8 | Cabbage | String Beans | With good results. |
| 10 | Carrots | Fall Planted Cabbage | As an experiment. Cabbage all winter killed. |
| 11 | Tomatoes | Fall Planted Cabbage | As an experiment. Cabbage all winter killed. |
| 17 | Beets | String Beans | A good plan if beets are sold promptly. |
| 19 | Spinach | Beets | With good results. |
| 20 | Cauliflower | Corn and Beans | Should work well if early variety of corn is planted. |
| 21 | String Beans | Spinach | With good results. |
| 22 & 23 | Early Irish Potatoes | " | One of the best combinations in two year's trial. |
| 29 | String Beans | Kale | With good results. |
| 38 | Old Strawberry Bed | Sweet Corn | All right if early variety of corn is planted. |
| 39 | " " " | String Beans | With splendid results. |
| 40 | " " " | Cabbage | Cabbage should be planted promptly. |
| 41 & 42 | " " " | Tomatoes | With fair results. Must have plants well started. |
| 43 & 44 | " " " | Irish Potatoes | With fair results. Use only early variety of potatoes. |
| 45 | " " " | Cabbage | With fair results. |
| 46 & 47 | " " " | Turnips & Kale | With good results. |

FIG. III.—Plots 4 and 5. Celery and Lettuce Following Peas and Spinach.

*3.—Improvement Cropping.*

In Plots 13, 14, 24, 25, 26, 27, 31, 32, 33, 34, and 36 containing bush lima beans, eggplants, peppers, pole lima beans, sweet corn, tomatoes, cabbage, and cauliflower respectively, good stands of crimson clover, to be plowed under next spring, were secured from seed sown the last week in July.

## Number of Days the Land was Occupied by Various Crops.

The third column which gives the number of days intervening between the date of planting and last sale will be helpful in making companion and succession cropping plans. The number of days given in some instances is larger than would be necessary where the entire crop may be removed as soon as it reaches maturity. This was impossible here because of the limited demands of our market. The most striking examples of this point are the beets in Plots 17 and 19, the carrots in Plot 10, also in the plots of parsnips, kale, spinach, potatoes, carrots, etc., which matured late in the fall. An examination of the date of the first sale as given in the fifth column of Table I will show when the crop might all have been removed in such cases had the market been large enough to absorb the total product quickly.

FIG. IV.—Same Plots as in FIG. III. Lettuce Ready to Cut.

### Gross Returns from Different Areas.

A summary of the three different areas into which the garden may be divided is of interest. From the three-acre block, containing Plots 1 to 30 inclusive, which had been in vegetables the longest, the total sales were $1,183.77, or at an average rate of $398.57 per acre. From the block of .6 acres, containing Plots 31 to 36 inclusive, the total receipts were $131.34, or at the rate of $218.90 per acre. From the 1.1 acres following the two-year-old strawberry bed, containing Plots 37 to 47 inclusive, the total receipts were $109.42, or at the average rate of $99.47 per acre. The total sales from the whole garden were $1,467.99 or at the rate of $312.33 per acre. It is interesting to note at this point that the average returns per acre for the season of 1913 were $267.04 and 1914 $247.09 per acre. The average gross receipts from the garden in 1913, 1914 and 1915 were $275.48 per acre. The difference between the receipts in the three years was due in part to the varying range of prices from year to year, the kind of a season and the difference in the quality of the land which was farmed.

## A SUMMARY OF RESULTS IN 1913, 1914 AND 1915.

A summary of the returns from each crop in 1915 together with the average yield per acre and the average returns per acre for the last three years is given in Table III.

TABLE III.—*A Summary of Yields and Returns in 1913, 1914, and 1915.*

| Relative Rank of Crops in Gross Returns, 1913-1915 | Name of Crop | Yield per Acre in 1915 | Av. Yield per Acre, 1913-15 | Av. Gross Returns per Acre in 1915 | Av. Gross Returns per Acre, 1913-15 |
|---|---|---|---|---|---|
| 17 | Beans—string, green and wax | 151 bu. | 192 bu. | $138.07 | $177.00 |
| 16 | Beans—pole and bush limas | 171 bu. | 138 bu. | 231.60 | 208.63 |
| 12 | Beets | 93.5 bu.<br>1045 dz. bun. | * | 354.40 | 257.13 |
| 10 | Cabbage—early and late | 15382 lbs. | 14864 lbs. | 206.82 | 273.44 |
| 13 | Carrots | ‡ | * | 315.15 | 252.97 |
| 1 | Celery | 2040 dz. | 1598 dz. | 763.70 | 533.22 |
| 22 | Corn—sweet | 620 dz. | 621 dz. | 118.68 | 94.59 |
| 19 | Cucumbers | 1285 dz. | 670 dz. | 240.30 | 128.61 |
| 2 | Eggplant | 555 dz. | 888 dz. | 365.00 | 462.73 |
| 8 | Kale | 823 bu. | 791 bu. | 267.33 | 369.56 |
| 5 | Lettuce | 9274 lbs. | * | 440.00§ | 378.83§ |
| 6 | Onions from sets | 1468 dz. bun. | 1175 dz. bun. | 525.95 | 370.95 |
| 14 | Onions from seed | 440 dz. bun.<br>315 bu. | 233 dz. bun.<br>175 bu. | 407.60 | 229.70 |
| 23 | Peas | 146 bu. | 71 bu. | 162.39 | 91.23 |
| 7 | Peppers | 234 dz.<br>29½ bu.<br>4 bbls. | * | 382.40 | 370.71 |
| 9 | Spinach | 428 bu. | * | 282.80§ | 288.48§ |
| 4 | Tomatoes—early and late | 370 bu. | 296 bu. | 424.40 | 405.66 |
| | **Crops Grown but Two Years.** | | | | |
| 3 | Cauliflower | 8264 lbs. | 8145 lbs. | 408.98 | 433.24 |
| 11 | Parsnips | 457 bu. | 366 bu. | 331.90 | 269.39 |
| 18 | Potatoes—Irish | 200 bu. | 215 bu. | 101.25 | 154.88 |
| 24 | Pumpkins | 2250 lbs. | 2605 lbs. | 22.50 | 46.80 |
| 15 | Radishes | 1475 dz. bun. | 1252 dz. bun. | 245.50 | 210.75 |
| 20 | Squashes | 180 dz.<br>3310 lbs. | † | 106.90 | 124.00 |
| 21 | Turnips | 228 dz. bun.<br>40 bbls.<br>30 bu. | * | 129.80 | 118.40 |

*See Table IV, Circular 17, for yields of 1913, 1914.
‡See Table I.
§These figures are estimated returns, assuming that the spinach and lettuce were planted in a solid block with rows one foot apart.
†See Table II, Circular 17, for yields of 1914.

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West Virginia University
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DEPARTMENT OF ANIMAL INDUSTRY

# SILOS AND SILAGE

A Good Silo Makes a Modern Cattle Feeding Shed Complete.

BY

E. W. Sheets and G. L. Oliver

Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

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# Silos and Silage

By E. W. SHEETS.

## INTRODUCTION.

For many years the silo has been successfully used on large beef and dairy cattle farms for the storage of the corn crop for feeding purposes during the winter months. Not until recent years, however, has the need for a silo become so apparent on small farms carrying from ten to twenty-five or more mature cattle or their equivalent. Evidence that the silo is essential to the economical production of milk, beef, and mutton is obtained from the results of experiments carried on at different experiment stations and from the thousands of livestock farmers who have changed from the old to the new method of storing and feeding their corn crops.

## ADVANTAGES OF SILAGE.

**Utilizes Entire Corn Plant.** One of the many reasons why the silo is of interest to West Virginia farmers is because hay has become so high in price that corn stalks are too valuable to lose. When harvested for silage the entire corn plant is taken from the field at a time when it contains approximately its greatest food value, and is preserved in as nearly the green state as possible. Analyses show that fully 37 percent of the digestible nutrients of the corn plant remains in the plant after removing the ear*, and when preserved and fed as dry stover or fodder at least one-half of this amount, or 20 percent of the entire food value of the corn plant, is lost by leaching and stalks not consumed by animals. The percentage of loss is even greater where shock corn or corn stover is fed to young cattle or sheep. Good silage properly fed is practically all consumed, thus eliminating the usual waste.

**Provides a Succulent Feed.** Silage is the cheapest and most palatable form in which a succulent feed can be provided for winter use. West Virginia is noted for its large acreage of bluegrass pasture. All kinds of livestock thrive upon it during the summer months. Silage, being a succulent

*Pennsylvania State College, First Annual Report.

roughage, in a large measure serves the same purpose in the winter ration that bluegrass pasture does in the summer ration.

**Is Valuable as a Summer Feed.** In many sections of the state there is urgent need for silage to tide stock over the dry season of August and September, when pastures become dry and parched.

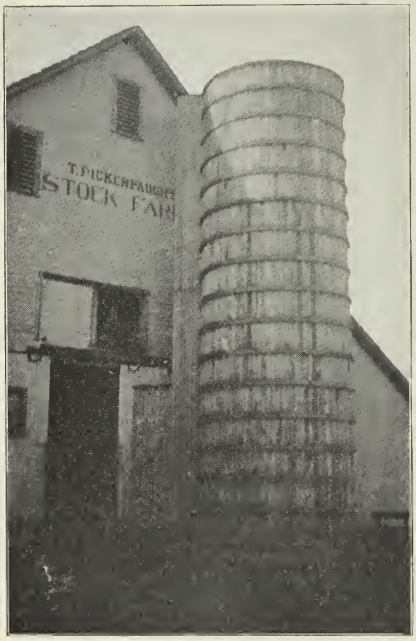


Fig. 1.—Home-made Stave Silo.

By the use of silage, animals can be fed until the first of June instead of the first of May, and by beginning to feed in the middle of September instead of at the first of November it is evident that pastures would be greatly benefited and in a few years could carry much more livestock than they can at the present time.

**Allows Use of Cheap Concentrates and Roughages.** Silage is a succulent roughage and as such permits the use of cottonseed meal, which at the present time is the cheapest source of protein. Owing to the physical effect upon the animal and the inconvenience in feeding, cottonseed meal cannot be so successfully fed alone with any of the other roughages.

Owing to the nature and feeding value of silage, cheap roughages can be profitably fed with it to wintering animals. It has been found that wheat straw and cottonseed meal, when fed with silage, are superior to timothy hay fed with silage for wintering steers*. The cost of the ration is materially reduced by feeding silage to all classes of livestock. This reduction is due to its low cost, nutritive value, and beneficial effects upon the utilization of the remainder of the ration fed.

**Is a Comparatively Cheap Feed.** The claim is generally made that silage is a cheap feed. This, however, depends primarily on who compiles the figures. The agronomy department of a certain institution recently gave out figures

*West Virginia Agricultural Experiment Station, unpublished data.

showing the profits that could be derived from growing silage at $6.00 to $7.00 per ton. The department of dairy husbandry of the same institution had made calculations showing the profits to be derived from dairying, silage being valued at $2.50 per ton.

The principal factors which usually control the cost per ton of silage are: first, cost of raising the crop; second, cost of putting the crop into the silo; and third, yield per acre of the crop. All of these factors are considerably influenced by the personal capacity of the farmer, so that various costs are reported under very similar conditions. Figures compiled by the department of farm management* show that the cost of producing silage in different parts of the state varies from $23.43 to $35.60 per acre, while the yields vary from 10 to 10.3 tons per acre. The cost of producing timothy or mixed hay varies from $7.04 to $8.35 per acre, with a yield of 1.2 to 1.3 tons. Table I gives the average yield of silage and mixed hay, and the average cost of growing and harvesting the crops.

**TABLE I.—Comparative Yield and Cost of Hay and Silage.**

| Average cost per acre to grow and harvest | | Average cost per ton to grow and harvest | |
|---|---|---|---|
| Silage | Hay | Silage, yield per acre 10.15 tons | Hay, yield per acre 1.25 tons |
| $29.51 | $7.70 | $2.91 | $6.16 |

One ton of mixed hay is equal in feeding value to three tons of silage. It is evident that while silage is a comparatively cheap feed, its greatest value is that it reduces to one-third the crop land necessary to feed or winter a given number of animals. The silo thus makes it possible, on the average, to put one-third of the present crop land in corn, one-third in soybeans or other crop for roughage, and to seed the other third of the roughest land now cultivated to permanent pasture, and at the same time to greatly increase the number of animals that can be wintered. By using only the more desirable land for crops and by carefully saving and applying the manure from the animals, the yield yer acre of forage can be greatly increased.

**More Livestock Can be Kept.** The silo makes it possible to put West Virginia agriculture on a sounder financial basis. Reports compiled by the West Virginia Agricultural Experiment Station* show that, on the average, the farms of the

*West Virginia Agricultural Experiment Station, unpublished data.

state which yield the largest incomes are those that maintain a relatively large number of livestock. It is evident, however, that there are many farms in the state where more livestock is needed, and the silo makes the keeping of more livestock possible.

## ESSENTIAL FEATURES OF A GOOD SILO.

After deciding to build a silo, the question which puzzles many people is, "What type of silo should I build?" There probably is no one type of silo which is equally well adapted to local conditions in all sections of the state. The factors which usually determine the type of silo to be constructed on any farm are: initial cost, availability of material, durability, and ease and quickness of construction. Since all of these factors must necessarily be considered in each individual case it is impossible to recommend any one type of silo which will suit all conditions. There are, however, some features in the construction of all silos without which silage will not keep in perfect condition or otherwise be satisfactory. These should be considered before deciding to build any one type.

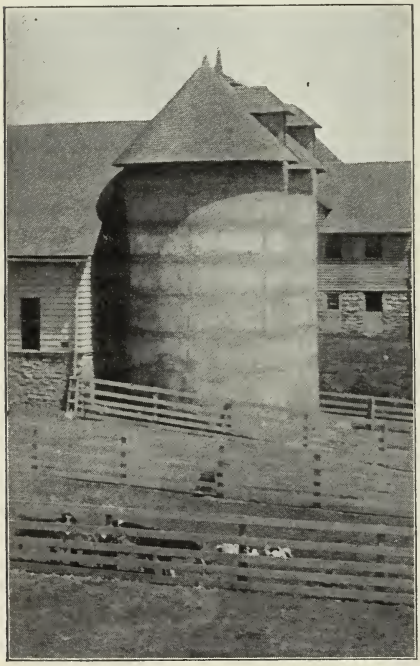

Fig. 2.—Home-made Concrete Silo.

**Cost.** The silo which will give the most and best service for the least money is, as a rule, the kind to build. While first cost is usually considered along with the cost of upkeep and the period of usefulness, there are no doubt cases where initial cost will be the deciding factor. In such cases it would seem to be the best policy to build a silo with the least possible outlay of money, even though its period of usefulness were comparatively short. In many instances it has been possible for individuals to build a silo of the home-made type where the construction of a more costly type was practically impossible.

**Efficiency.** There is one fundamental principle which must be observed in silage making. The green corn must be preserved in a form that will exclude all air. The silo with a wall most nearly airtight will keep silage best. It has been proved that practically airtight walls can be constructed from a variety of materials. The juice of the green corn or the water added aids in this exclusion of air and so the wall should be constructed in such a way as to make it not only airtight but also watertight. If the wall is constructed of materials which absorb large quantities of moisture from the silage it will allow mold to develop around it. Walls of concrete or plastered silos are oftentimes objectionable for this reason, unless treated with a cement wash, coal tar, or other preparation.

**Durability.** The wall should not only be efficient in keeping silage but should be durable. Any material used in the construction of a silo is expensive, so that the material which will last over the longest period of years and give satisfaction, when permanency is desired, will be cheapest in the end, even though the first cost will be slightly greater.

**Convenience.** The above-ground type of silo is more convenient than the below-ground type. It is much easier to throw silage down than to draw it up. The continuous door is also more convenient that the intermittent door, since the opening is always nearer the level of the silage. It is not desirable, as a rule, to go more than two or three feet below ground or to extend more than 18 feet in diameter, for convenience.

**Attractiveness.** Any properly constructed silo adds to the attractiveness of a farm and enhances its value. Like other farm buildings, if improperly or poorly constructed, it soon becomes dilapidated, is an eye-sore and a sign of shiftlessness, and shows poor judgment on the part of the owner. On the other hand, a silo which will be attractive and remain so with the least possible expense and effort is one that will be a thing of beauty and a satisfaction to its owner.

**Shape.** The only shape of silo to be recommended is a round one, this form being cheapest, most durable, and satisfactory for keeping the silage. The wall should be perpendicular and smooth on the inside so that silage will not adhere to it, and in order to permit even settling and packing without leaving air pockets in the outer edge of the silage.

**Floor.** A cement floor in a silo is not necessary under ordinary clay soil conditions, in fact it is not desirable. Where there is danger of seepage into the silo, or where the soil is very gravelly or sandy so that the drainage from the silo will be very rapid, it is always desirable to lay a floor.

**Roof.** A roof is not essential. It adds greatly, however, to the looks of the silo, giving it a more finished appearance. A roof probably helps to decrease freezing and adds to the comfort of the feeder during stormy weather.

**Chute.** A chute is necessary to prevent waste of silage in throwing it from the top of the silo. It also adds greatly to the convenience in feeding when the silo is near the barn, as it should be in most cases.

## DIMENSIONS OF SILO TO BUILD.

**Diameter.** The inquiry is often made, "What size silo should I build?" The diameter depends upon the number and class of animals to be fed. To keep silage perfectly fresh, two to three inches should be removed daily from the entire surface during warm weather, and from one to two inches during cold weather. The depth of silage to be removed daily, however, will depend very largely upon the care used in taking the silage out. The surface in all cases should be left smooth, firm, and level. It is not considered practical to build a silo for less than 10 to 12 head of mature cattle, or their equivalent, as the amount which will be removed daily is too small to keep the silage in perfect condition. A mistake frequently made and a common cause of poor silage is building a silo too large in diameter for the number of livestock fed.

Fig. 3.—Patent Stave Silo.

The following table shows the number of animals that may be fed from silos of various diameters by removing an average of two inches per day when various quantities are fed:

**TABLE II.—Relation of Herd to Diameter of Silo.**

| Diameter | Pounds Removed Daily | Number of Animals Fed Various Quantities per Head per Day | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 35 lbs. | 30 lbs. | 25 lbs. | 20 lbs. | 15 lbs. | 10 lbs. | 5 lbs. |
| 8 | 320 | 9 | 10 | 12 | 16 | 21 | 32 | 64 |
| 10 | 523 | 15 | 17 | 21 | 26 | 35 | 52 | 105 |
| 12 | 754 | 21 | 25 | 30 | 38 | 50 | 75 | 151 |
| 14 | 1030 | 29 | 34 | 41 | 51 | 69 | 103 | 206 |
| 16 | 1340 | 38 | 44 | 53 | 67 | 88 | 134 | 268 |
| 18 | 1685 | 48 | 56 | 67 | 84 | 112 | 168 | 337 |
| 20 | 2100 | 60 | 70 | 84 | 105 | 140 | 210 | 420 |

The amount of silage fed varies with the class of animals to which it is fed. Silage should not comprise the only roughage fed to livestock. Some dry roughage such as hay or straw, depending upon the class of animals, should be fed with it. The following table shows the number of animals that may be fed by removing an average of two inches per day from a silo of a given diameter, when the amounts usually recommended are fed:

**TABLE III.—Amounts of Silage to Feed Different Kinds of Animals.**

| Kind of Stock | Pounds to be Fed Daily | Number of Animals 2 Inches per Day will Feed from a Silo of a Given Diameter | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 8 ft. | 10 ft. | 12 ft. | 14 ft. | 16 ft. | 18 ft. | 20 ft. |
| Dairy Cows | 35 | 9 | 15 | 21 | 29 | 38 | 48 | 60 |
| Beef Cows | 35 | 9 | 15 | 21 | 29 | 38 | 48 | 60 |
| Wintering Steers | | | | | | | | |
| 2 yrs. old | 30 | 10 | 17 | 25 | 34 | 44 | 56 | 70 |
| 1 yr. old | 25 | 12 | 21 | 30 | 41 | 54 | 67 | 84 |
| Calves | 18 | 17 | 29 | 42 | 57 | 74 | 93 | 116 |
| Breeding Ewes | 3 | 106 | 174 | 251 | 343 | 446 | 562 | 700 |
| Fattening Sheep | 3 | 106 | 174 | 251 | 343 | 446 | 562 | 700 |
| Fattening Lambs | 2 | 160 | 261 | 377 | 515 | 670 | 842 | 1050 |

Silage may be fed in very limited amounts to horses and mules, if only good silage, fed with great care, is used. Serious results, however, are frequently reported when apparently the best of care has been used.

**Height.** The height of silo to build depends upon the length of the feeding period. For wintering or growing animals a filled silo 30 feet in height is sufficient in most cases, as this will allow the feeding of two inches per day for 140 to 150 days, which is the usual length of the feeding period. A silo of greater height is recommended for feeding dairy cows or other animals where a longer feeding period is desirable.

**Feeding Capacity.** Knowing the amount of silage to be fed daily and the length of the feeding period, one can figure out the amount of silage which will be needed for the entire herd for the year. Practice has shown that the amount which can be fed from a silo is at least 10 percent less than the amount contained in it after settling, that is at the beginning of the feeding period. This loss usually consists of spoiled silage, waste, and shrinkage. The following table is not for the purpose of giving the capacities of silos of different dimensions, but shows the amount of silage which can usually be fed from a silo of a given diameter, with different depths of silage after settling:

**TABLE IV.—Feeding Capacity of Silos.**

| Depth in Feet of Silage After Settling | Amount in Tons which can be Fed from a Silo Having an Inside Diameter of | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 ft. | 10 ft. | 12 ft. | 14 ft. | 15 ft. | 16 ft. | 18 ft. | 20 ft. |
| 24 | 20 | 31 | 44 | ..... | ..... | ..... | ..... | ..... |
| 26 | 23 | 34 | 50 | ..... | ..... | ..... | ..... | ..... |
| 28 | 25 | 38 | 55 | 75 | ..... | ..... | ..... | ..... |
| 30 | 29 | 42 | 60 | 82 | 95 | ..... | ..... | ..... |
| 32 | ..... | ..... | 67 | 90 | 104 | 118 | ..... | ..... |
| 34 | ..... | ..... | 72 | 98 | 113 | 129 | ..... | ..... |
| 36 | ..... | ..... | 78 | 107 | 122 | 140 | 176 | ..... |
| 38 | ..... | ..... | ..... | 115 | 132 | 150 | 191 | 235 |
| 40 | ..... | ..... | ..... | ..... | 142 | 162 | 205 | 253 |
| 42 | ..... | ..... | ..... | ..... | 153 | 174 | 221 | 272 |
| 44 | ..... | ..... | ..... | ..... | ..... | 186 | 236 | 291 |
| 46 | ..... | ..... | ..... | ..... | ..... | ..... | 252 | 311 |
| 48 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 331 |

## TYPES OF SILOS IN WEST VIRGINIA.

Owing to the many types of silos used in the state only those most commonly used and of approved types will be discussed at any length. The types of home-made silos which are recommended are the wooden-hoop stave silo, the wooden-hoop plastered silo, and the concrete silo; the patent silos recommended are stave and hollow tile block. Other types of both home-made and patent silos, however, have been used and in many instances gave entire satisfaction.

## HOME-MADE SILOS.

**Wooden-Hoop Stave Silo.** Perhaps the first type of home-made silo to be built in the state was the wooden-hoop stave silo. The earlier silos of this type were built somewhat on the same order as those of the present day, although rather plain in structure. When the modern wooden-hoop stave silo is constructed of tongued and grooved material of good quality a good silo at a very low cost can be built. Including roof and foundation the average cost complete of a silo of this type varies somewhat in different parts of the state, but on the average a 60-ton silo will cost from $1.00 to $2.00 per ton capacity, depending somewhat upon the availability of material and the cost of labor. The cost per ton capacity decreases as the size increases.

**Wooden-Hoop Plastered Silo.** The wooden-hoop plastered silo is constructed very similarly to that of the wooden-hoop stave silo, having in addition a coat of plaster on the inside. One advantage of the wooden-hoop plastered silo is that rough and somewhat cheaper lumber can be used in its construction. The cost of this type of silo is about the same as that of the wooden-hoop stave silo.

The chief advantages of the wooden-hoop stave and plastered types of silos are low initial cost and availability of material in most agricultural communities. These silos are efficient and will last under ordinary conditions from six to fifteen years, depending upon construction and material used. Where capital is limited, material readily available and labor cheap, a silo of either of these types is recommended.

**Concrete Silo.** The concrete silo has the advantage of other types in permanency and stability. A well-constructed concrete silo will last indefinitely. For the man with sufficient capital who wants a silo for a long period of years, and who can obtain materials for concrete at a reasonable cost, the building of a concrete silo is advisable. The necessary repairs are reduced to a minimum, the first expense being practically the only expense. The chief objections to the concrete silo are its cost and its somewhat difficult construction. On the average, silos of this type will cost from $2.00 to $4.00 per ton capacity, depending upon the size of the silo, the availability of materials, the cost of forms, and the cost of labor.

**Concrete Block and Brick Silos.** These silos have been used to some extent and are entirely satisfactory when properly constructed. They are, however, expensive and have no advantages to recommend them over the concrete silo.

## PATENT SILOS.

**Stave Silo.** Among the patent silos most commonly used is the stave silo. Silos of this type have become very popular in recent years because of their comparative cheapness, and ease and quickness of construction. Generally speaking the stave silo excels in these particulars, although there are many sections of the state where lumber or sand and gravel may be obtained at a nominal cost, and where the price of the stave silo is excessive. Under such conditions the home-made stave silo, the plastered silo, or even the concrete silo may be considerably cheaper and equally as satisfactory. Silos of this type will cost from $2.00 to $3.50 per ton capacity, depending upon the make and the material used.

Fig. 4.—Hollow Tile Block Silo.

**Tile Silo.** A silo constructed of hollow tile blocks reinforced with steel is finding a place on many farms. The air space undoubtedly provides some protection against the freezing of the silage, although this is of relatively little importance. It is apparently durable when properly constructed, but owing to its rather recent introduction it is difficult to say how it compares in durability with other types. If good tiles adapted for the purpose can be secured at a reasonable cost there is no reason why this silo should not come into more general use. The cost of a silo of this type varies from $3.00 to $5.00 per ton capacity.

## LOCATING THE SILO.

After having decided to build a silo of a definite size and type, its location is of considerable importance. If convenient, the silo should be located so as to shut off as little light from the barn as possible. The location of the barn, the approach to the proposed silo and other conditions being equal, the silo should be located on the north side. As a rule it should be so near the barn that the chute will open directly into the interior as near the place where it is to be fed as possible.

## THE MAKING AND FEEDING OF SILAGE.

The making and feeding of silage to different kinds of livestock will be discussed in a separate publication, which may be secured free upon request to the Director of the West Virginia Agricultural Experiment Station.

# Building Instructions for Home-Made Silos

By G. L. OLIVER,

In co-operation with U. S. Dept. of Agriculture.

Owing to the fact that complete plans for constructing patent silos are provided by the manufacturers, building plans, including bill of materials, are provided in this bulletin only for silos of the home-made type. The demand for more detailed information concerning the construction of silos of this type has made it necessary to rewrite Circular 8 of the West Virginia Agricultural Experiment Station, by W. D. Zinn, which gave instructions for building wooden-hoop silos. Acknowledgement is made to Mr. Zinn for his helpful suggestions in the preparation of these plans.

## STAVE AND PLASTERED SILO.

Table V gives the approximate bill of materials for silos of different dimensions, including foundations. It does not, however, include a bill of materials for the roof.

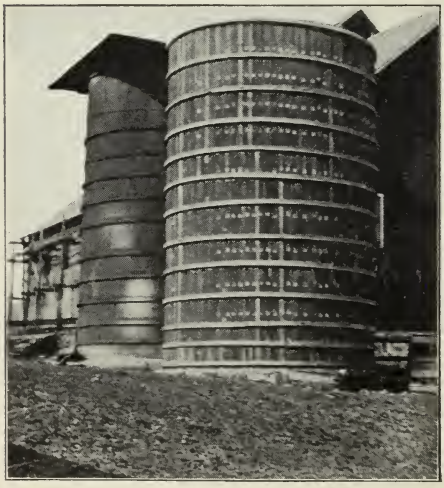

Fig. 5.—Home-made Silos on Farm of W. D. Zinn That Have Kept Silage for Fourteen Years.

**Stave Material—Item* A.** While not necessary it is advisable if a planing mill is convenient, to have the material for staves edged and planed on one side. Any lumber which is sound and straight can be used for this purpose. Although objectionable from the standpoint of appearance, knotty lumber, if sound, may be used for the plastered silo. If flooring instead of the material above is to be used for staves, be sure that it is of good

*For the amounts of materials specified in items A to I reference should be made to Table V.

quality and that it contains no holes of any kind. Use the smooth surface on the inside. Add about one-third to the bill for tongue and groove.

**Hoop Material—Item B.** In determining the length of material to be used for making hoops, find the circumference of the proposed hoop and match the length most economically. It is well to have this material cut ¾ of an inch thick and afterwards dressed to ½ inch if a planer is convenient. Otherwise insist upon having the material uniform, and not thicker than ½ inch. A thickness of ⅜ inch is sufficiently strong, as three thicknesses or layers will be used. Any pliable wood such as second-growth oak, white oak preferred, or elm may be used. Beveled weatherboarding of good grade or No. 1 ⅜-inch yellow pine ceiling may be used for the construction of hoops with good results.

**Door Material—Item C.** The material for the doors should be No. 1 yellow pine flooring with 3¼ inch face.

**Plastering Laths—Item D.** These should be made from material that will bend easily. Ordinary plastering laths 4 feet long are best. If somewhat dry when ready to use, soak in water. Sometimes chicken wire and metal laths are used but they are more expensive and not so satisfactory as wooden laths.

**Door Facing—Item E.** Quarter round may be used, but if it is not easily secured, 1 x 2-inch planed boards will answer, or a piece of flooring may be split to the desired size.

**Cement—Item F.** The quantity of cement given is for the plastering and is mixed 1 part cement, 3 parts clean, sharp sand, and 10 percent screened, hydrated lime. A 1 part cement, 3 parts sand, 5 parts crushed stone concrete mixture is used for the foundation. By using large stones in the bottom of the foundation the quantity of cement can be slightly reduced.

**Sand—Item G.** The sand includes the quantity required for plaster as well as that to be used in the foundation. This sand must be screened, clean, and sharp.

**Stone—Item H.** It is desirable to have this material broken up in pieces from 1 to 2 inches in diameter.

**Anchor Irons—Item I.** These can be made from old wagon tires, and should be about 4 feet long, with one end turned up about 2 inches to a right angle, so that they will not pull out of the concrete. The opposite end should have two ½-inch holes punched or drilled, one 2 inches and the other 24 inches from the end (see Fig. 7).

TABLE V.—Approximate Bill of Materials for Constructing Home-made Silos of Different Dimensions.*

| ITEM | 8 x 24 20 tons | 8 x 30 29 tons | 10 x 24 31 tons | 10 x 28 38 tons | 10 x 30 42 tons | 12 x 24 44 tons | 12 x 28 55 tons | 12 x 30 60 tons | 12 x 32 67 tons | 14 x 30 82 tons | 14 x 36 107 tons | 15 x 30 95 tons | 16 x 32 118 tons | Materials |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 576 | 720 | 720 | 840 | 900 | 864 | 1008 | 1080 | 1152 | 1260 | 1512 | 1360 | 1608 | feet of 1 x 4" boards |
| B | 367 | 454 | 468 | 520 | 576 | 520 | 600 | 640 | 680 | 736 | 856 | 768 | 884 | feet B. M. ½ x 4" boards |
| C | 152 | 190 | 152 | 176 | 190 | 152 | 176 | 190 | 204 | 190 | 228 | 190 | 204 | feet of matched t. and g. flooring |
| D | 950 | 1270 | 1150 | 1350 | 1450 | 1400 | 1650 | 1750 | 1900 | 2050 | 2550 | 2200 | 2500 | plastering laths |
| E | 48 | 60 | 48 | 56 | 60 | 48 | 56 | 60 | 64 | 60 | 72 | 60 | 64 | feet quarter round |
| F | 17 | 18 | 21 | 22 | 23 | 26 | 28 | 29 | 29 | 31 | 33 | 34 | 37 | bags cement |
| G | 2¼ | 2¼ | 2½ | 2½ | 2½ | 2¾ | 2¾ | 3 | 3 | 3¼ | 3¼ | 3¼ | 3½ | cubic yards sand |
| H | 3.2 | 3.2 | 3.8 | 3.8 | 3.8 | 3¾ | 3¾ | 3¾ | 3¾ | 4.4 | 4.4 | 4.7 | 5 | cubic yards stone |
| I | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | pieces of old wagon tire |
| J | 40 | 40 | 40 | 45 | 50 | 55 | 60 | 60 | 60 | 65 | 70 | 75 | 80 | pounds nails, 4, 6, 8, and 10 d. |

*The capacity given is the usual amount which may be fed from a silo of given dimensions.

**Foundation.** The first step to be taken up is the construction of the foundation. Having determined the diameter of the silo, the interior diameter of the foundation is laid off so that it will be 4 inches smaller than the inside diameter of the silo, the object being to have the silo rest near the inner edge of the foundation rather than in the middle or on the outer edge. The foundation is marked off by driving a stake in the ground at the center of the proposed silo. To this is fastened, with a 12-penny nail, one end of a straight strip long enough to reach from the stake to the outer edge of the foundation (see Fig. 6). The positions of the inner

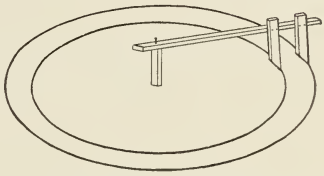

Fig. 6—Method of Marking Off the Foundation.

Fig. 7.—Anchor Irons Set in Foundation.

and outer edges of the foundation wall, which are 12 inches apart, are marked on this strip, and two short, straight-edged pieces are nailed on at right angles to the strip at these points. By keeping the strip level and using sliding markers two circles can be laid off on the ground, which will correspond to the inner and outer edges of the foundation. The soil can be

taken from between these lines to a depth of two feet, or below the frost line. Care should be taken that the walls of the excavation are perpendicular, as they will answer as a form for the concrete, which is mixed and poured in to the level of the ground. Place the anchor irons in the foundation while it is being made so that they will come on the outside of the hoop (see Fig. 7), and have the upper end of the anchor 30 inches from the proposed top of the foundation. When the cement has set, drive stakes in between the concrete and the earth about 2 feet apart on the inner and outer sides of the foundation, and tie together with strips across the top. Complete the construction of the form by bending ½-inch boards around and nailing to the stakes. Fill with the concrete mixture and smooth off. The outer edge should be about 1 inch lower than the inner edge.

Fig. 8.—When the Uprights are Braced This Form will be Ready for Making the Hoops.

**Construction of Hoops.** The hoops are most easily made on a circular form about 6 or 7 feet high. The diameter of the form is to be made 2 to 4 inches greater than that of the inside diameter of the silo, depending upon whether a flooring or plastered wall is to be constructed.

With a 10-penny nail, fasten one end of a strip to a stake which has been driven in level ground. From this nail measure the radius or one-half the diameter of the form and saw off the strip at this point. Drive an 18-inch stake into the ground about 1 inch toward the center from the end of the strip. From this point sight across the center stake and similarly

locate another stake. Continue this operation so that a circle will be formed with an even number of stakes about 2 feet apart. Fasten in an upright position to the stakes of the circle straight-edged 2 x 4's about 6 feet long, so that their outer edges will be even with the end of the strip. These should be plumbed before fastening. When this has been completed tie the opposite 2 x4 uprights across the center with strips which are the exact length of the diameter of the form. Nail the tie pieces together in the center (see Fig. 8). The uprights or 2 x 4's should be plumbed in two directions before bracing.

The hoops are made as follows of three layers of the hoop material with broken joints: With 6-penny nails fasten the right end of the hoop material which is the inner layer to a 2 x 4 studding. Keep this level and bend around the form to the left. At the second or third studding begin the middle layer by nailing to the studding through the first piece of inner layer with three 6-penny nails. The outer layer of the hoop is started on the third, fourth or sixth upright. Do not allow the joints of any two layers to come within 12 inches of each other. Nail all the joints well with 6-penny nails. Use 8, 10, or even 12-penny nails in drawing the hoops to the studding. Do not hesitate to drive nails into the studding and nail every 3 to 6 inches between the studding. Complete the hoops by fitting the respective joints of the three layers.

Start the second hoop on the next studding to the left and continue as before. If the lumber is in good condition three men should build three hoops an hour. At least two men will be required to build the hoops, but a crew of three men is better. This work may be done in the spring and at odd times before building the silo. It is better to make the hoops when material is pliable. If the lumber dries out, it can be rendered more pliable by soaking it in water.

Slightly better hoops may be made by beveling the ends so that they will overlap. A foot adz may be used for this purpose.

When all the hoops have been completed, tear out the interior braces and tie pieces. The hoops should go on the foundation either in the order or in the reverse order in which they were made, and in the same position with respect to one another. In order to do this, number the hoops from top to bottom with a heavy pencil. Draw a vertical line in about five places around the form from top to bottom. These marks will be of use when the hoops are raised. With a crowbar, mattock or piece of heavy timber pry out all the studding and clinch all nails.

**Constructing Scaffold.** The scaffold can be constructed by splicing 2 x 4's together on the ground, making four uprights as long as the desired height of the silo. These uprights are raised and placed about 18 inches toward the center from the hoops and in such positions that they will be equally distant apart. They are then plumbed and braced. Scaffold floors are placed about every 7½ feet from the top of the foundation. Splice enough of the stave material so as to reach from the top of the foundation to the top of the proposed silo, and indicate on these pieces where the hoops are to be placed.

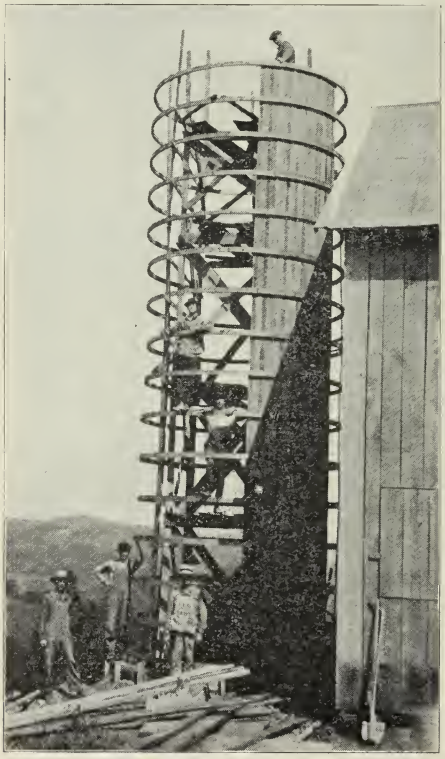

Fig. 9.—Nailing the Staves on.

**Spacing Hoops.** The hoops should be spaced as follows: Beginning at the foundation, the center of the first hoop should be located 6 inches above the foundation. The second and third hoops are spaced 22 inches on center, the fourth and fifth hoops 23 inches, and all others 2 feet apart, except the last two, which should be spaced 23 inches. This is done in order that joints in the staves may be made at any place where there is a hoop. By so doing, lumber 8 feet or more in length may be used. After the scaffold has been completed the first hoop is raised, using three ropes for this purpose. The first hoop is supported by nailing two sound 1 x 4's across the top of the scaffold where the pieces used for spacing the hoops indicate that the top of the silo is to be. These pieces are then fastened to the hoop, which has been raised, at the places indicated by the marks which were made while the hoops were on the form, and similarly fastened to the bottom hoop, which is resting on the foundation. The top hoop is then plumbed with the bottom hoop, and the

two 1 x 4's are raised or lowered as necessary in order to keep the top hoop rigidly in place. It is an easy matter to raise the remaining hoops and fasten them in their proper places by nailing to the pieces used for spacing. Plumb the hoops on one side, where the door is located, and brace well to the scaffold.

**Nailing the Staves on.** Begin on the side where the door is to be, drop a perpendicular line from top to bottom and mark on each hoop where the first stave is to be placed. Nail the first staves to the hoops, using two nails for each hoop. Continue breaking joints (see Fig. 9) and plumbing the hoops about every five feet until about one-half or two-thirds of the staves have been put on. Mark off the space for doors and door facings, beginning on the opposite side. Nail the staves on as before. This is recommended because of the fact that it is important to have the hoops at the doors as uniform as possible.

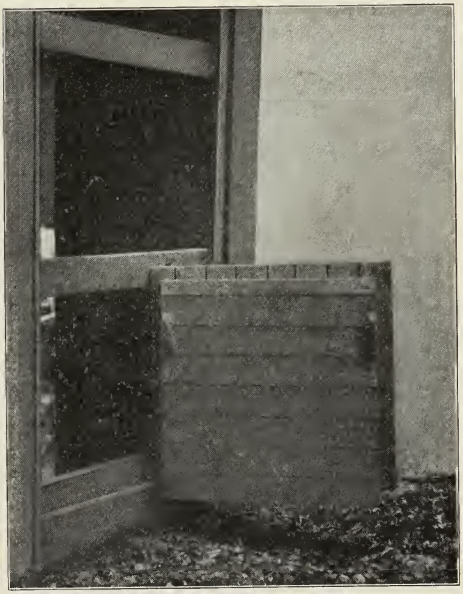

Fig. 10.—Doors are Constructed of Two Layers of Flooring.

**Making Doors and Door Frames.** For door frames use flooring which has a 1-16 inch bevel made so that the doors will fit into the frames from the inside of the silo and be continuous from top to bottom. By using eight pieces of 3¼-inch face flooring, taking off the tongue and groove of the outside pieces and beveling so that they will fit the bevel of the door frame, a door about 25½ inches wide can be made. The length of doors is determined by the spacing of the hoops from center to center.

The doors are made of two layers of flooring (see Fig. 10). the outer layer fitting into the bevel of the facing, while the ends extend from the center of one hoop to the center of the other. The inner layer overlaps the outer layer about 1¼ inches on each side, the ends being fitted 1¼ inches below the ends of the other layer. A piece of quarter round

fits against the inner layer on the sides. The two layers are then put into the opening, nailed together, and a batten nailed on. The doors may be made straight instead of assuming the curvature of the silo (see Fig. 11). In this event no batten will be needed. Instead of using batten the outside layers run in a horizontal position and the space between the door and the hoop is filled with a piece of wood cut to conform to the curvature of the hoop.

**Lathing and Plastering.** The laths if dry should be soaked in water so that they will bend easily. Begin at the top of the silo and nail the laths, from ⅜ to ½ inch apart, direct to the staves. Break joints as much as possible, as this will slightly strengthen the silo. One coat of a cement plaster is usually sufficient, using 1 part Portland cement and 3 parts clean, sharp sand by volume, to which is added 10 percent screened, hydrated lime. If dry, dampen the laths before applying the mixture, as dry wood absorbs the moisture from the plaster. The finished wall should be as smooth as it is possible to make it, since this will reduce friction and allow the silage to settle properly. The plastering may be done in a wet season. At any rate do not allow the wall to dry too rapidly. If it dries too rapidly, dampen with water. It is a good plan to go over the wall with a coat of cement wash mixed to the right consistency and applied as whitewash. A mixture of equal parts of coal tar and gasoline is also excellent. This can be applied over the cement wash.

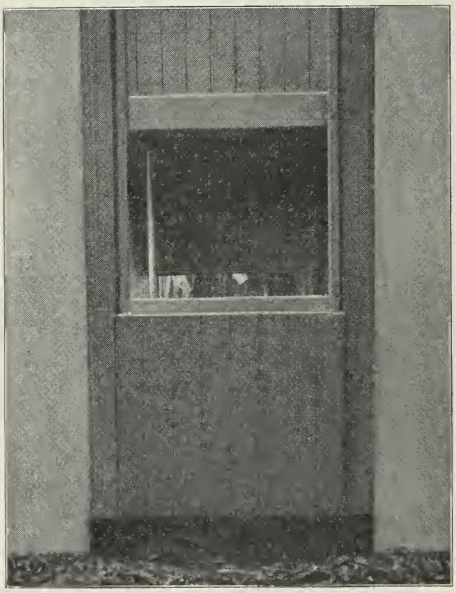

Fig. 11.—Straight Door Set in Door Frame.

**Roof.** The roof illustrated in Figure 12 is made of light material and the sections can be easily opened and closed. The chief advantage is that the capacity of the silo is in-

creased. If a gable roof is to be used it should be at least ½ pitch. The cost of a roof for a ten foot silo is about $15.00. A gambrel roof is still better (see Fig. 4) but will cost about 80 percent more.

**Waterproofing Hoops.** After the silo has been completed the hoops should receive a coat of creosote, applied hot. A mixture of equal parts coal tar and gasoline or a mixture consisting of 1 gallon of coal tar and 1 pound of pulverized rosin is sometimes applied, the latter mixture being heated and stirred over a slow fire. A little oakum should be added and the preparation applied to the hoops while it is hot. This forms a waterproof coat which greatly increases the durability of the hoops.

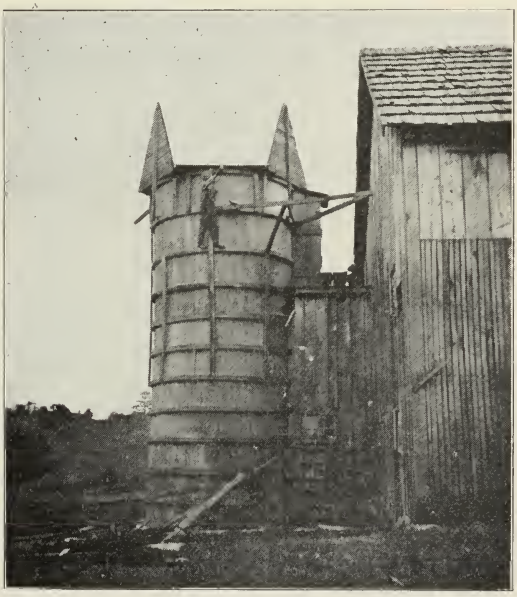

Fig. 12.—A Roof Which Increases the Capacity of the Silo.

**Concrete or Other Types of Silos.** Owing to limited space, building plans, including bill of materials, for concrete or types of silos other than those recommended are not given, but will be furnished upon request.

Bulletin 158 July, 1916

# West Virginia University Agricultural Experiment Station

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# The Apple as Affected by Varying Degrees of Dormant and Seasonal Pruning

TECHNICAL BULLETIN

Heavy Dormant Pruning.

Light Dormant Pruning.

BY
W. H. Alderman and E. C. Auchter

Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

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# The Apple as Affected by Varying Degrees of Dormant and Seasonal Pruning

By W. H. ALDERMAN and E. C. AUCHTER.

## INTRODUCTION.

Probably one of the oldest and most universally practiced of orchard operations is pruning. Earliest records in horticulture contain repeated references to this practice, and no modern writer would think of publishing a general treatise on orcharding without devoting a considerable portion of it to detailed directions regarding pruning operations. Like many other phases of horticulture, the subject of pruning has been so much discussed that original information has been lost sight of and oft-repeated theories and statements of general observations have been blindly accepted as fundamental facts around which have been formulated far-reaching principles of plant growth. That much teaching has probably been erroneous is not to be wondered at; the surprising thing is that so much has been correct. The greater is the surprise when, after a long search through foreign and American writings, are found, out of the vast amount of published material, barely a scant half dozen accounts of well-planned experimental work having to do with the pruning of the apple, while the other tree fruits are even less well provided for. The meager results secured from these experiments in widely separated parts of the world are not always clear cut and have had little effect in molding the current theories and principles of pruning. The more important details of some of these experiments will be considered later in connection with the work of the West Virginia Agricultural Experiment Station.

## OUTLINE OF THE WEST VIRGINIA EXPERIMENTS.

**History.** In the spring of 1911, A. L. Dacy, then assistant horticulturist at the West Virginia Agricultural Experiment Station, began a pruning experiment in an orchard on the farm of Arthur Sheets at Lost Creek, West Virginia. This orchard is located on a side hill in a Westmoreland silty clay loam soil of only moderate fertility and is typical of many

West Virginia plantings. The orchard was put out in the spring of 1909, but the trees in that portion of the orchard in which the pruning experiment was later located were nearly all destroyed by rabbits during the ensuing summer and winter. Of the replants in 1910 a few were lost so that it was not until 1911, the time of the beginning of the experiment, that the trees were all in place. At the time it was not appreciated that the differences in the ages of the trees would seriously affect the experiment, but it has now been found necessary to eliminate from consideration all data secured from trees not planted in 1910 and which were one year old at the time the first experimental pruning was made. This elimination has reduced the number of trees from forty-five to twenty-three, a number all too small upon which alone to base final conclusions. Fifteen trees of each of the three varieties, York Imperial, Grimes, and Rome, were originally included but the reduction leaves seven, seven, and nine trees respectively. The orchard was planted in corn as an intercrop in 1911, followed by a cover crop of crimson clover. In 1912 it was seeded down and has been in sod ever since, a small crop of hay having been removed annually. Tree growth during the past two years has been somewhat lessened by this practice.

In the spring of 1912 the experiment was greatly extended by adding four other orchards to the test. The first of these was a young orchard planted in 1911 upon property now owned by the Berkeley Springs Orchard Company of Berkeley Springs, West Virginia. The soil in this orchard is a rather thin gravelly or shaley clay loam of about the same fertility as that in the Sheets orchard. The land, except in one spot where a small depression has forced the elimination of a little over one-half of one plot, slopes quite uniformly and gently to the east. The experiment originally included one hundred and eighty-seven trees, somewhat unequally divided among the varieties, Stark, Gravenstein, Rome, and Stayman Winesap, but the above-mentioned soil inequality and the usual run of accidents to growth and development have rendered it necessary to discard thirty-six trees, thus leaving one hundred and fifty-one trees which are uniform and comparable in every way. The orchard was planted in an intercrop of corn in 1911 with cowpeas planted at the last cultivation as a cover crop. In 1912 and 1913 tomatoes were planted as intercrops, followed by crimson clover sowed at the last cultivation. In 1914 the clover was allowed to stand and was plowed under after it had made a good growth. In 1915 tomatoes were again grown and were followed by a cover crop of rye.

The two orchards already described have furnished material for a study of the effects of pruning up to bearing age upon the trees. The next two orchards to be described taken together illustrate the influence of pruning upon orchards just coming into bearing. These orchards, the one belonging to Lupton Brothers and the other to the Grimes Golden Orchard Company, are both near Martinsburg, West Virginia, and are located upon fertile limestone soil, the surface of which is broken by numerous limestone outcrops. In the Lupton orchard a block of ninety York Imperial, six years old, was chosen. The soil treatment in this orchard consisted of cultivation each year with occasionally a crop of corn between the rows. A strip of sod, however, was left in each of the tree rows. In the Grimes Golden orchard two blocks of forty-five trees each of seven-year-old York Imperial and Grimes were chosen. The choice was an unfortunate one, however, as the Grimes row subsequently bore so many Gano apples that it was found necessary to abandon it bodily. In the York Imperial block some trees not true to name were found, so that the total number of trees was reduced to thirty-seven. The cultural treatment in this block has been sod in 1912, sod with tree rows cultivated in 1913, and cultivation followed by good natural weed cover crops in 1914 and 1915.

The fifth test was in C. W. Boyer's orchard at Bunker Hill, West Virginia, and furnishes an opportunity for a study of the effects of pruning on older bearing trees. The orchard is somewhat elevated over the general level of the Shenandoah valley and is on fertile limestone soil. Thirty-five trees each of fifteen-year-old York Imperial and Arkansas (Mammoth Black Twig) varieties were selected for the test. The trees were not in a very vigorous condition at the beginning of the experiment but under the influence of cultivation, leguminous cover crops, and some fertilization, the entire orchard is now in excellent condition. Only two crops of Arkansas, in 1914 and 1915, and one very heavy crop of York Imperial, in 1914, have been secured, apple rust and the disastrous freeze of 1913 being responsible for the failures. Lack of uniformity in development, obviously not due to pruning, and mixed varieties have led to the discarding of three trees in this orchard.

The accompanying table indicates the number of trees of each variety in the several orchards together with the treatment accorded each plot.

TABLE I.—The Number of Trees and Varieties in Each Plot.

| PRUNING TREATMENT | Sheets Orchard | | | Berkeley Springs Orchard | | | | Grimes Golden Orchard | Lupton Orchard | Boyer Orchard | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | York Imperial | Grimes | Rome | Stark | Gravenstein | Rome | Stayman Winesap | York Imperial | York Imperial | York Imperial | Arkansas |
| Heavy dormant | 1 | 2 | 4 | 19 | 17 | 13 | 24 | 5 | 10 | 5 | 5 |
| Moderate dormant | 2 | 1 | 2 | .... | 7 | 8 | 19 | 5 | 10 | 5 | 5 |
| Light dormant | 1 | 2 | 3 | 4 | 10 | 11 | 19 | 5 | 9 | 5 | 5 |
| Heavy dormant and early summer | .... | .... | .... | .... | .... | .... | .... | 1 | 9 | 5 | 4 |
| Moderate dormant and early summer | .... | .... | .... | .... | .... | .... | .... | 2 | 10 | 4 | 5 |
| Early summer | .... | .... | .... | .... | .... | .... | .... | 5 | 10 | 5 | 5 |
| Midsummer | 3 | 2 | .... | .... | .... | .... | .... | 5 | 10 | 4 | 5 |
| Repeated summer | .... | .... | .... | .... | .... | .... | .... | 4 | 10 | .... | .... |
| Ringing | .... | .... | .... | .... | .... | .... | .... | 5 | 10 | .... | .... |
| Total | 7 | 7 | 9 | 23 | 34 | 32 | 62 | 37 | 88 | 33 | 34 |

Total number of trees under experimentation.....366

**Definition of Treatment.** Before considering the results of the experiment it is necessary first to designate clearly what was actually done with the several plots in order to furnish a basis for an interpretation of the results and for a comparison with other experiments. In the Berkeley Springs orchard the three general plots receiving heavy dormant, moderate dormant, and light dormant pruning were subdivided into a number of minor divisions based upon the amount of heading back of terminal growth practiced in addition to the normal branch thinning. The amounts of terminal growth removed are as follows:

### Terminal Growth Removed in Heavy Pruning.

Plot A.—Three-fourths annually for five years, followed by branch thinning only.

Plot B.—Two-thirds annually for five years, followed by branch thinning only.

Plot C.—One-half annually for five years, followed by branch thinning only.

Plot D.—Three-fourths first year, two-thirds second year, one-half third year, one-third fourth year, one-fourth fifth year, followed by branch thinning only.

### Terminal Growth Removed in Moderate Pruning.

Plot E.—One-fourth annually for five years, followed by branch thinning only.

Plot F.—Two-thirds first year, one-third second year, one-fourth third year, followed by branch thinning only.

Plot G.—One-half first year, one-third second year, one-fourth third year, followed by branch thinning only.

**Terminal Growth Removed in Light Pruning.**

Plot H.—One-half first year, one-fourth second year, followed by branch thinning only.

Plot I.—One-fourth first year, followed by branch thinning only.

Plot J.—Not headed back, branch thinning only.

It soon became apparent that it was not practicable to make such small variations in treatment in orchards not entirely under the control of the Agricultural Experiment Station and so far removed from headquarters. Consequently only the general grouping of heavy, moderate, and light pruning will be considered in this bulletin. In the Sheets orchard the heavy pruning corresponds to plot D in the preceding outline, moderate pruning to plot F, and light pruning to plots I and J.

In the Grimes Golden orchard and the Lupton orchard heavy pruning was secured by a severe thinning and heading back of the new growth each year, except in 1915 when heading back was discontinued. It is extremely difficult to maintain a system of heavy pruning upon bearing trees without removing a large amount of bearing wood and thus checking seriously the fruitage of the tree. This fact led after two or three years to a gradual reduction of the severity of this type of pruning. A proper relation, however, was always maintained between the heavy, moderate, and light pruning. The moderate pruning in these orchards included a slight heading back of terminal growth the first few years; but in the light pruning, branch thinning only was practiced with no heading back. On the bearing trees in the Boyer orchard no heading back was performed, the difference between heavy, moderate, and light pruning being secured by varying the amount of branch thinning. In all orchards dormant pruning took place between March 20 and April 4 of each year.

The summer pruning practiced was of practically the same type as the dormant pruning and in amount of wood removed corresponded closely with the moderate dormant pruning. The early summer pruning was performed in 1912 and 1913 between May 25 and May 31 but in the last two years was shifted to June 9 to 11, as the earlier pruning seemed to be much too early. The midsummer pruning took place each year between July 8 and 15, while the repeated summer pruning was simply a combination of the early and midsummer prunings and took place on the dates mentioned. In this region fruit bud formation in the apple begins from June 20 to July 1. Early summer pruning was performed just previous

to this period and midsummer pruning just following it after the period of most rapid growth was completed. It will be noted that, in two orchards, ringing was practiced. This phase of the work consisted of the removal, at the time of the early summer pruning, of a narrow strip of bark around the trunk of each tree and near the ground. During this girdling operation care was taken not to injure the cambium, the soft sappy layer of tissue next to the wood. Ringing was performed but once only on each tree.

## PART I.—The Effects of Varying Degrees of Dormant Pruning upon Trees of Different Ages.

### The Effects of Heavy, Moderate, and Light Pruning upon the First Five Years' Growth of Trees.

The data presented under this head are taken entirely from the Berkeley Springs and Sheets orchards. It will be noted that the results are much more clearly cut in the former orchard than in the latter. It is thought that too few trees were used in the Sheets orchard to overcome tree individuality and small inequalities in soil fertility which are difficult to detect but which are very liable to occur upon a hillside. The results obtained in the Berkeley Springs orchard, which is planted in a more uniform soil and contains a greater number of trees, impress the writers as being much more indicative of true conclusions than do the results of the Sheets experiment.

**Character of Annual Terminal Growth and Amount of Wood Removed.** It was observed throughout the experiment wherever heavy pruning was performed and particularly where the heading back was severe that a rank terminal growth was secured. This result is strictly in accord with general teaching and observation and has undoubtedly led to establishing firmly in the professional's as well as in the layman's mind the principle that heavy pruning tends to increase the production of wood. Most certainly at first glance this would appear to be true but it will be shown later that the conclusion is probably due to an optical illusion caused by the rank growth of a few branches. Table II shows data upon the annual terminal growth taken from the Sheets orchard only.

TABLE II.—Average Length of Annual Terminal Growth with Length, Weight, and Number of Branches Removed per Tree. (Sheets Orchard.)

Average Length of Terminal Growth (Inches).

| | 1911 | 1912 | 1913 | 1914 | 1915 | Average |
|---|---|---|---|---|---|---|
| Heavy pruning | | 42.6 | 39.2 | 24.7 | 23.5 | 32.3 |
| Moderate pruning | | 40.6 | 20.8 | 14. | 13.5 | 22.2 |
| Light pruning | | 29.4 | 15.5 | 9.3 | 9.9 | 16.0 |

Average Length Removed (Feet).

| | 1911 | 1912 | 1913 | 1914 | 1915 | Average |
|---|---|---|---|---|---|---|
| Heavy pruning | 17. | 39. | 112.5 | 135.1 | 91.9 | 79.1 |
| Moderate pruning | 15.9 | 24.8 | 107. | 121.8 | 52.7 | 64.4 |
| Light pruning | 6.2 | 15.7 | 70.6 | 75.9 | 36.3 | 40.9 |

Average Weight Removed (Pounds).

| | 1911 | 1912 | 1913 | 1914 | 1915 | Average |
|---|---|---|---|---|---|---|
| Heavy pruning | | | 2.57 | 2.26 | 1.36 | 2.06 |
| Moderate pruning | | | 2.25 | 1.6 | .68 | 1.51 |
| Light pruning | | | 1.46 | 1.5 | .54 | 1.17 |

Average Number of Branches Removed.

| | 1911 | 1912 | 1913 | 1914 | 1915 | Average |
|---|---|---|---|---|---|---|
| Heavy pruning | 7.7 | 26.7 | 39.3 | 81.4 | 71.4 | 45.3 |
| Moderate pruning | 10. | 32.6 | 46.8 | 84.2 | 41.6 | 45. |
| Light pruning | 3.1 | 15.1 | 33.5 | 43.3 | 27.7 | 24.5 |

In this orchard the pruning was heaviest at the beginning and gradually decreased as the orchard grew older. The increase in size of the trees more than offset this, however, so that the amount of wood removed in terms of length, weight, and number of branches increased each year until in 1915, when there was a marked decrease. This decrease was due partly to the fact that the trees made a slightly less than normal growth in 1914 and partly to a general lightening of pruning in trees of that age.

**Total Length of Annual Growth.** As a quantitative measure of the growth of the trees each year, one variety (Stark) was selected in the Berkeley Springs orchard and each year careful measurements of the total new longitudinal growth were taken together with the amount of this growth removed at the annual prunings. It must be understood that this does not represent an exact measure of the volume of wood produced each year for the heavily pruned trees produced fewer but larger shoots than were produced upon the lightly pruned trees. Consequently the longitudinal growth of the heavily pruned blocks weighed more per running foot than did that of the lightly pruned blocks. This difference in character of the terminal growth is more than offset by the annual increase in diameter of the main branches. These branches in the

lightly pruned trees are longer, not having been headed back, and consequently the total volume of the ring of new growth put on by them is greater than that on the heavily pruned trees. It is interesting to note from Table III that for the first two years, 1912 and 1913, the heavily pruned trees produced as much as or slightly more growth than did the lightly pruned trees.

Fig. 1.—Row on Left Heavily Pruned, Row on Right Lightly Pruned (Stark Variety).

Unfortunately the lightly pruned plot at one end dipped into a depression where the soil seemed to be richer and growth was correspondingly greater than in the remainder of the plot. To overcome this difficulty a number of trees were discarded so that this plot finally contained four trees and the heavily pruned plot contained nineteen trees.

**TABLE III.—Average Total Length per Tree of Annual Longitudinal Growth and Length in Feet Removed Each Year. (Stark Variety).**

| | HEAVY PRUNING | | | LIGHT PRUNING | | | |
|---|---|---|---|---|---|---|---|
| Season of Growth | Average Total Length of Growth | Average Length Removed | Percent Removed | Average Total Length of Growth | Average Length Removed | Percent Removed | Gain in Feet Over Heavy Pruning |
| 1911 | 4.41 | 3.3 | 74.8 | 5.58 | 3.44 | 61.6 | ..... |
| 1912 | 16.25 | 12.91 | 79.4 | 15.51 | 4.78 | 31.4 | — .74 |
| 1913 | 41.53 | 33.16 | 79.8 | 34.33 | 13.89 | 41.4 | — 7.20 |
| 1914 | 84.08 | 49.17 | 58.4 | 99.39 | 22.12 | 22.2 | +15.31 |
| 1915 | 161.74 | ..... | ..... | 224.89 | ..... | ..... | +63.15 |

It appears quite clear from this table that the removal of about 75% of the new growth at the first and second prunings (pruning at planting time not considered) may have a beneficial effect upon tree growth but that after that time severe pruning should be avoided.

In order to see if light pruning produced the same tendency toward greater growth in other varieties, careful measurements were made of the total longitudinal growth produced in 1915 on a considerable number of trees in each orchard. The results of this study are shown in detail in Table IV. While there is some deviation in the case of the Gravenstein at Berkeley Springs and in the mixed York Imperial, Rome, and Grimes block in the Sheets orchard, it can be plainly seen that the general tendency is to put on a new growth in **inverse ratio** to the amount of wood removed.

TABLE IV.—Average Total Length per Tree in Feet of Longitudinal Growth in 1915.

| Variety | No. of Trees | Heavily Pruned Trees | No. of Trees | Lightly Pruned Trees |
|---|---|---|---|---|
| Stayman Winesap | 11 | 125.12 | 12 | 152.93 |
| Rome | 6 | 120.75 | 7 | 174.86 |
| Gravenstein | 6 | 144.66 | 10 | 121.75 |
| Stark | 19 | 161.74 | 4 | 224.89 |
| York Imperial, Grimes, and Rome in Sheets Orchard | 7 | 204. | 6 | 188. |
| Average for all varieties | | 131.25 | | 172.49 |

**Size and Form of Trees.** It would appear from Table III that the heavily pruned trees averaged less annual longitudinal growth than did the others and as they were cut back severely they consequently should be somewhat smaller in size. Casual observation indicated this to be true but to avoid any mistake the heights and widths of all trees in the two orchards were measured in 1915 at the close of the season's growth.

TABLE V.—Average Height and Width of Trees.

| Variety | Type of Pruning | No. of Trees | Height in Feet | Width in Feet |
|---|---|---|---|---|
| Stayman Winesap | Heavy | 24 | 7.32 | 5.29 |
| Stayman Winesap | Moderate | 19 | 7.89 | 5.52 |
| Stayman Winesap | Light | 19 | 9.50 | 5.65 |
| Rome | Heavy | 13 | 7.45 | 3.68 |
| Rome | Moderate | 8 | 8.18 | 4.17 |
| Rome | Light | 11 | 9.16 | 4.23 |
| Gravenstein | Heavy | 17 | 7.43 | 4.05 |
| Gravenstein | Moderate | 7 | 6.83 | 4.19 |
| Gravenstein | Light | 10 | 8.94 | 4.34 |
| Stark | Heavy | 19 | 7.57 | 5.17 |
| Stark | Light | 4 | 10.79 | 6.85 |
| York Imperial, Grimes, and Rome in Sheets Orchard | Heavy | 7 | 9.55 | 4.83 |
| | Moderate | 5 | 9.73 | 6.17 |
| | Light | 6 | 10.50 | 7.10 |

It will be seen from Table V that in no instance is the height or width of trees as great in the case of heavy and moderate pruning as it is in the case of light pruning (see illustration on cover and figs. 1, 2, and 3) and in only one instance, height of Gravenstein trees, is moderate pruning exceeded by heavy pruning. In the latter instance the width of the moderately pruned Gravenstein is greater than that of the heavily pruned trees.

Fig. 2. — Stayman Winesap Given Light Annual Dormant Pruning.

Fig. 3.—Stayman Winesap Given Heavy Annual Dormant Pruning.

**Effect upon Form of Tree.** The question naturally arises as to what effect heavy and light pruning, particularly heavy and light heading back, may have upon the form of trees. The effect is more easily illustrated than described. Figures 4 to 15 show typical trees of the different groups as they appeared each year. It is noticeable that the primary limb scaffold branches are longer following light pruning than following heavy pruning, and that the secondary branches start out at a greater distance from the trunk. This gives the tree a sprawling habit during the first few years which is in sharp contrast to the compact, neatly-built trees in the more heavily pruned plots. After the third or fourth year, however, this difference is not so noticeable, due to the thickening of scaffold limbs and the filling in of laterals in the lighter pruned

## HEAVILY PRUNED STAYMAN WINESAP.

Fig. 4.—After Pruning, Spring of 1913.

Fig. 5.—Before Pruning, Spring of 1914.

## LIGHTLY PRUNED STAYMAN WINESAP.

Fig. 10.—After Pruning, Spring of 1913.

Fig. 11. — Before Pruning, Spring of 1914.

## HEAVILY PRUNED STAYMAN WINESAP.

Fig. 6.—After Pruning, Spring of 1914.

Fig. 7,—Before Pruning, Spring of 1915.

## LIGHTLY PRUNED STAYMAN WINESAP.

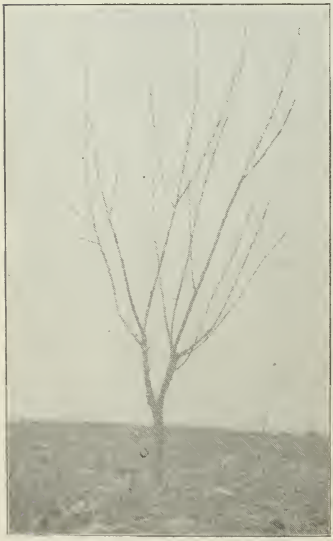

Fig. 12. — After Pruning, Spring of 1914.

Fig. 13. — Before Pruning, Spring of 1915.

## HEAVILY PRUNED STAYMAN WINESAP.

Fig. 8.—After Pruning, Spring of 1915.

Fig. 9.—Before Pruning, Spring of 1916.

## LIGHTLY PRUNED STAYMAN WINESAP.

Fig. 14. — After Pruning, Spring of 1915.

Fig. 15.–Before Pruning, Spring of 1916.

trees. It is doubtful if trees which have not been headed back at all the first or second year will ever acquire as satisfactory a form as those the branches of which have been shortened during this period. In the interest of strength and sturdiness of tree, the primary branches should not be too long and the secondary branches should spring not farther than twelve or sixteen inches from the trunk. This can be accomplished only by judicious heading back the first and probably the second seasons. After this time light pruning is to be preferred.

**Stockiness as Indicated by Diameter of Trunk and Branches.** Up to this point it has been shown that the individual terminal growth of the heavily pruned trees averages larger than that of the more lightly pruned blocks, but that a greater total length or extension of terminal growth took place under light pruning. It has also been shown that trees pruned lightly are taller and broader than those pruned heavily. So far no data have been presented bearing upon the increase in thickness of trunk or branches: Unless such data are presented it might be argued that the longer longitudinal growth of the lightly pruned plots would result in spindling and weak branches with less total volume of growth than in the heavily pruned plots. In addition to throwing light upon this point it is believed that records showing actual increase in diameter of trunk and perhaps of main branches constitute the most reliable evidence of tree vigor securable without actually removing the tree with its roots from the soil and weighing it.

In the Berkeley Springs orchard records of the diameters of the trunks of all trees have been kept each year, the diameters being taken in each case at a point just below the head. The detailed records of these data are show in Table VI. The trees in the several plots were very uniform in the beginning except those in the moderately pruned Gravenstein and lightly pruned Stark and in this case although undersized at the beginning both blocks overcame the handicap within four years or less.

An interesting feature brought out in Table VI is that there is practically no difference between the three plots in increase of trunk diameter for the first two years of the experiment, but in the year 1914 when the trees were making their fourth season's growth, being their third under experiment, the more lightly pruned trees began to forge ahead of the others. In 1915 this difference became still more pronounced. This phenomenon corresponds very closely with the way the Stark trees behaved with regard to their total longitudinal growth (see Table III) and confirms the opinion held by the authors that a fairly heavy pruning the first two

**TABLE VI.—Increase in Diameters of Tree Trunks in Inches. (Berkeley Springs Orchard.)**

| VARIETY | Type of Pruning | Number of Trees | Diameter 1911 | Diameter 1912 | Diameter 1913 | Diameter 1914 | Diameter 1915 | Increase in Four Years |
|---|---|---|---|---|---|---|---|---|
| Stayman Winesap | Heavy | 24 | .36 | .74 | 1.14 | 1.48 | 1.95 | 1.59 |
| Stayman Winesap | Mod. | 19 | .35 | .75 | 1.15 | 1.56 | 2.06 | 1.71 |
| Stayman Winesap | Light | 19 | .34 | .75 | 1.17 | 1.61 | 2.20 | 1.86 |
| Rome | Heavy | 13 | .34 | .70 | 1.02 | 1.25 | 1.61 | 1.27 |
| Rome | Mod. | 8 | .34 | .72 | 1.13 | 1.47 | 1.97 | 1.65 |
| Rome | Light | 11 | .35 | .70 | 1.04 | 1.65 | 2.13 | 1.78 |
| Gravenstein | Heavy | 17 | .32 | .72 | 1.13 | 1.47 | 1.97 | 1.65 |
| Gravenstein | Mod. | 7 | .27 | .71 | 1.05 | 1.32 | 1.90 | 1.63 |
| Gravenstein | Light | 10 | .31 | .72 | 1.11 | 1.38 | 2.27 | 1.96 |
| Stark | Heavy | 19 | .33 | .73 | 1.15 | 1.57 | 2.17 | 1.98 |
| Stark | Light | 4 | .28 | .68 | 1.16 | 1.87 | 2.91 | 2.63 |
| Weighted Average of all varieties.. | Heavy | 73 | .34 | .73 | 1.12 | 1.46 | 1.95 | 1.61 |
| | Mod. | 34 | .33 | .73 | 1.11 | 1.49 | 2.02 | 1.69 |
| | Light | 44 | .33 | .72 | 1.12 | 1.59 | 2.26 | 1.93 |

years is desirable since it does not retard growth and aids in forming a well-shaped tree.

Goethe,* a German investigator, cites a case in which trunk measurements were made of a block of eighty-eight two-year-old apple trees sixty of which had been heavily pruned and twenty-eight lightly pruned. The heavily pruned trees averaged 8.4 cm. in circumference and the lightly pruned ones 9.5 cm. The following year the same trees were re-measured and the heavily pruned ones had gained 1.1 cm. in circumference while the others had increased 2 cm., or a gain of .9 cm. in favor of light pruning. In another block of three-year-old apple trees 37 trees had been unpruned and 49 heavily pruned. At the beginning of the fourth season the unpruned trees averaged 10.7 cm. in trunk circumference and the pruned trees averaged 8.6 cm. At the close of the season the unpruned trees had increased 2.6 cm. and the pruned trees 1.1 cm., or a gain of 1.5 cm. in favor of the light or no pruning. The same author called attention to the condition of two groups of sycamore trees, each 20 years old. One group which had been heavily pruned averaged .7 meters in circumference and the other which had been unpruned averaged 1.05 meters.

In 1915 we wished to learn if the main limbs behaved the same as the trunks and increased in diameter inversely as to

*The Effect of Annual Pruning on the Growth of Trees, R. Goethe, Ber. K. Lehranst obst. Wein U. Gartenbau Geisenheim, 1899-1900, pp. 54-56.

the amount of pruning. To secure this information all the scaffold limbs and the central leaders were calipered just above their point of union at the head. At first, trees having three, four, or five branches were kept separate and comparisons were made only between trees of similar branching habit, but as the relation between heavy and light pruning remained practically the same in each type, the results are thrown together for the sake of convenience.

**TABLE VII.—Diameter in Inches of Main Branches in 1915. (Berkeley Springs Orchard.)**

| VARIETY | Heavy | Moderate | Light | Increase of Light Over Heavy Pruning |
|---|---|---|---|---|
| Stayman Winesap | 1.125 | 1.17 | 1.43 | .305 |
| Rome | .92 | 1.20 | 1.25 | .33 |
| Gravenstein | 1.20 | 1.01 | 1.19 | —.01 |
| Stark | 1.18 | ..... | 1.45 | .27 |
| Weighted average of all varieties | 1.12 | 1.15 | 1.36 | .24 |

It is very clear from Table VII that the branch growth on the lightly pruned trees is neither "spindling" nor weak. On the contrary, these lightly pruned trees averaged larger by a quarter of an inch in diameter than did the heavily pruned trees, and if we may judge from the way the trunks are behaving this difference will probably become more pronounced in later years.

It is to be regretted that the data gathered from the Sheets orchard are not as conclusive nor the results as clear cut as in the Berkeley Springs orchard. In fact, the authors at first had serious doubts regarding the propriety of publishing the data secured in the Sheets orchard because of the experimental error to which it is subjected. The original number of trees in the experiment was too small to permit of very accurate work and as a number have since been discarded the results when taken alone mean little. They do, however, tend to bear out in many respects the work in the Berkeley Springs orchard and for this reason it was finally decided to include them in the report. The trunk measurements were not taken each year, but at the close of the 1915 season's growth the circumferences of the trees in the three plots were taken and are shown in Table VIII.

**TABLE VIII.—Circumference of Tree Trunks. (Sheets Orchard.)**

| Type of Pruning | Circumference |
|---|---|
| Heavy | 8.46 inches |
| Moderate | 9.62 inches |
| Light | 9.91 inches |

In this instance the lightly pruned trees exceeded those heavily pruned by one and one-half inches in circumference. These facts furnish valuable corroborative evidence when taken in connection with the work in the other young orchard.

At the beginning of the experiment the average diameter of the first scaffold limbs was taken at their base. The following year these limbs were again measured as were also the terminal shoots which extended the scaffold limbs. Each subsequent year the diameter of the terminal growth of each main branch was secured and also the diameter of each of the preceding year's growth on these limbs. Thus we are able to study the influence of heavy, moderate, and light pruning not only upon the diameter of the terminal growth following the pruning, but also upon the sections of the branch one, two, three, and four years back from the terminal. It is recognized that heavy pruning involving heading back produces a long and correspondingly thick terminal growth but a more important question is whether it tends to thicken the branch back of the point at which the cut was made. A summary of these measurements is shown in Table IX.

**TABLE IX.—Increase in Inches in Diameters of Main Limbs. (Sheets Orchard.)**

| Total Age of Branch Section | Average Increase Each Year | | | | | Average Yearly Increase | Total Diameter, 1915 | Average Increase After First Year | Total Increase After First Year |
|---|---|---|---|---|---|---|---|---|---|
| | 1911 | 1912 | 1913 | 1914 | 1915 | | | | |
| **HEAVY PRUNING, 7 TREES.** | | | | | | | | | |
| 5 years | .332 | .198 | .170 | .187 | .102 | .198 | .989 | .164 | .657 |
| 4 years | ..... | .408 | .046 | .170 | .124 | .187 | .748 | .113 | .340 |
| 3 years | ..... | ..... | .306 | .147 | .082 | .178 | .535 | .115 | .229 |
| 2 years | ..... | ..... | ..... | .311 | .071 | .191 | .382 | .071 | .071 |
| 1 year | ..... | ..... | ..... | ..... | .268 | ..... | ..... | ..... | ..... |
| **MODERATE PRUNING, 5 TREES.** | | | | | | | | | |
| 5 years | .332 | .196 | .182 | .160 | .098 | .194 | .968 | .157 | .636 |
| 4 years | ..... | .396 | .105 | .119 | .118 | .148 | .738 | .114 | .342 |
| 3 years | ..... | ..... | .242 | .094 | .098 | .145 | .434 | .096 | .192 |
| 2 years | ..... | ..... | ..... | .226 | .066 | .146 | .292 | .066 | .066 |
| 1 year | ..... | ..... | ..... | ..... | .204 | ..... | ..... | ..... | ..... |
| **LIGHT PRUNING, 6 TREES.** | | | | | | | | | |
| 5 years | .257 | .157 | .161 | .168 | .184 | .185 | .927 | .168 | .670 |
| 4 years | ..... | .296 | .064 | .144 | .123 | .157 | .627 | .110 | .331 |
| 3 years | ..... | ..... | .225 | .096 | .094 | .138 | .415 | .095 | .190 |
| 2 years | ..... | ..... | ..... | .198 | .076 | .137 | .274 | .076 | .076 |
| 1 year | ..... | ..... | ..... | ..... | .196 | ..... | ..... | ..... | ..... |

Although the data in this table are largely negative in nature there are a few things that should be pointed out as being at least suggestive. First, the table shows that in each case the terminal growth has a greater average diameter when the pruning is heavy. (The diameter of terminal growth is shown by the first decimal in the first column of each line.) Then, ignoring the terminal growth which is always heavy following heavy pruning and referring to the second column from the right side of the table under the caption "Average Increase After First Year" we find that there is practically no difference in favor of any method of pruning. The lightly pruned plot has a slight advantage in the two- and five-year-old sections but loses in the three- and four-year-old sections. It should be noticed that in 1915 the lightly pruned block made a greater increase in its several sections, terminal growth excluded, than did either of the other two blocks. This may support previous evidence that heavily pruned trees make better growth the first year or two but that lightly pruned trees overtake and pass them by the third to fifth season.

It may be worth while to refer at this point to work* done at the English Experimental Fruit Farm at Woburn. A large number of terminal shoots 36 inches long were selected. These shoots were divided into four groups, the first of which was headed back to 6 inches, the second to 12 inches, the third to 24 inches, and in the fourth the terminal bud only was removed. After one season's growth the basal enlargements of each original shoot were measured and were found to bear the following relation to each other:

| | |
|---|---|
| 6-inch group | 100 |
| 12-inch group | 114 |
| 24-inch group | 117 |
| 36-inch group | 124 |

As these comparisons were made from branches on the same tree they would seem to indicate pretty definitely that the lighter the pruning, the greater will be the increase in diameter of wood growth back of the cut. This is strictly in accordance with the work in the Berkeley Springs orchard, and as far as trunk measurements are concerned also in the Sheets orchard, except in this work the increase in favor of light pruning was sometimes deferred for two or more years. It should be stated that the trees in the Woburn experiment just quoted were of bearing age while the ones in this experiment were not yet in bearing.

**Early Bearing.** The trees in both orchards are too young to have produced much fruit up to this time but a small

*Bedford and Pickering, Woburn Experimental Fruit Farm, Seventh Report, 1907.

amount has been secured from the Sheets orchard and a few specimens formed in the Berkeley Springs orchard in 1915 but were picked off by the owners so as not to check tree development. In both orchards some bloom was found in 1914 and 1915, and a good set of fruit buds has been recorded for the 1916 crop.

**TABLE X.—Effect of Pruning upon Early Bearing. (Berkeley Springs Orchard).**

| VARIETY | Type Pruning | Bloom Clusters Per Tree, 1914 | Percent Bloom Per Tree, 1915 | Percent Fruit Buds Per Tree, 1916 |
|---|---|---|---|---|
| Stayman Winesap.. | Heavy | 0 | 1 | 50.4 |
| Stayman Winesap.. | Moderate | .16 | 6.4 | 72.4 |
| Stayman Winesap.. | Light | .05 | 13 | 86.3 |
| Rome | Heavy | 0 | 0 | 17 |
| Rome | Moderate | 1.6 | 9 | 66 |
| Rome | Light | 2.4 | 10 | 51 |
| Gravenstein | Heavy | 0 | 0 | 36 |
| Gravenstein | Moderate | 0 | 0 | 30 |
| Gravenstein | Light | 0 | 0 | 54 |
| Stark | Heavy | 0 | 0 | 34 |
| Stark | Light | 0 | 0 | 61 |

**TABLE XI.—Effect of Pruning upon Early Bearing. (Sheets Orchard.)**

| Type Pruning | Bloom Clusters Per Tree, 1914 | Fruits Per Tree, 1914 | Bloom Clusters Per Tree, 1915 | Fruits Per Tree 1915 | | Percent Fruit Buds Per Tree, 1916 |
|---|---|---|---|---|---|---|
| | | | | Number | Wgt. (lbs) | |
| Heavy | .14 | 0 | 1.86 | .7 | .25 | 3.7 |
| Moderate | 3.4 | .2 | 40.00 | 12.2 | 3.35 | 20 |
| Light | 15.5 | 2.0 | 175.00 | 24 | 6.64 | 38 |

Table X and Table XI need little explanation. In both orchards the results are exactly the same and in both cases light pruning has shown a strong tendency to induce early bearing and heavy pruning has retarded bearing. In the Woburn experiment already referred to, similar results were secured on dwarf trees. In that experiment, records for 12 years were reported in three periods. The yield of the moderately pruned trees was taken as 100 and proportional values were attached to the other groups with the following results:

| | 1st 5 Yrs. | 2nd 5 Yrs. | 12th Yr. |
|---|---|---|---|
| Heavy pruning | 75 | 50 | 5 |
| Moderate pruning | 100 | 100 | 100 |
| Light pruning | 90 | 150 | 145 |
| No pruning | 220 | 200 | 275 |

The same experiment station reported the yields of 53 varieties of standard and 80 varieties of dwarf trees for one year, contrasting moderate and heavy pruning.

| | Standards | Dwarfs |
|---|---|---|
| Heavy pruning | 28 | 30 |
| Moderate pruning | 100 | 100 |

There can seem to be no question that young apple trees if given little or no pruning will come into bearing earlier than if pruned heavily.

**Volume of Growth Affected by Pruning.** In measuring the effect of pruning or of any other factor upon tree growth, a single set of measurements is often of little value. The true vigor of the tree can only be determined by finding the actual volume or weight of new tissue formed. In young trees this volume is confined to the leaves and to the wood of tops and roots. In older trees the fruit must, of course, be also considered. There is no feasible way of measuring exactly the yearly increase in new tissue without actually digging up a number of trees each season, but a comparative estimate that is reasonably accurate may be made if sufficient data have been secured. Regarding the young trees in the two orchards under discussion five salient facts were determined by sufficiently careful measurements. First, the lightly pruned trees are taller and broader than those heavily pruned. Second, the lightly pruned trees have annually made the longer total growth. Third, the main branches of the lightly pruned trees though longer are larger in diameter than those of the heavily pruned plots. Fourth, the lightly pruned trees have the larger trunks. Fifth, while little or no fruit has been produced, the lightly pruned trees have exhibited a tendency toward early bearing, as evidenced by bud and flower formation, and heavy pruning has shown a tendency to retard bearing. No measurements of root growth have been possible but since the lightly pruned trees are the larger, have made the longer annual growth, have the thicker limbs and trunks, and have shown the greater tendency toward fruitfulness, it can only be concluded that they are making the greater annual production of new tissue.

The Woburn Experiment Station* in its seventh report gives corroborative data upon the point under discussion. After dwarf trees had been under experiment 12 years, it was found necessary to thin the planting and the opportunity was taken to weigh carefully the trunks and branches and as much of the

*Bedford and Pickering, Woburn Experimental Fruit Farm, Seventh Report, 1907.

root systems as was formed within a radius of 18 inches from the trunks. The heavily pruned trees were found to be 16% lighter than the moderately pruned trees, while those left unpruned were 20% heavier than those moderately pruned. Estimates were made of the amount of wood removed in pruning and, as the total weight of this wood did not nearly equal the difference in weight of the trees, it was assumed that the unpruned trees had actually produced more new tissue during the 12 years than had the ones severely pruned.

## Effects of Varying Degrees of Dormant Pruning Upon Orchards Just Attaining Bearing Age.

The Grimes Golden and Lupton orchards were used in this test. The variety was York Imperial in each instance. The trees in the Grimes Golden orchard were seven years old at the beginning of the test and were arranged five in a plot, while the Lupton orchard was six years old with ten trees in a plot. The former orchard was making good growth and the latter only a fair growth at the beginning of the experiment; but both carried too many scaffold limbs which, because of crowding, had made a long but weak growth. An attempt was made to correct this trouble in the experimental plots and in all blocks some large limbs were removed at the start.

**Character of Annual Terminal Growth and Weight of Wood Removed.** The terminal growth following pruning responded in the same manner as did that in the younger orchards; that is, the heavier pruned trees produced longer and heavier shoots than did those lightly pruned.

TABLE XII.—Character of Annual Terminal Growth and Weight of Wood Removed.

| | Grimes Golden Orchard | | | Lupton Orchard | | |
|---|---|---|---|---|---|---|
| | Heavy Pruning | Moderate Pruning | Light Pruning | Heavy Pruning | Moderate Pruning | Light Pruning |
| Length of growth in inches, 1911 | 12.41 | 14.42 | 15. | 7.87 | 7.30 | 7.75 |
| Ave. length of growth in inches, 1912-'15 | 14.79 | 12.68 | 11.36 | 15.87 | 10.74 | 8.37 |
| Diameter of growth in inches, 1911 | .214 | .211 | .22 | .159 | .156 | .166 |
| Ave. diam. of growth in inches, 1912-'15 | .215 | .18 | .172 | .218 | .181 | .166 |
| Ave. amt. in pounds of wood removed, 1912-'15 | 8.37 | 7.81 | 3.78 | 3.87 | 3.39 | 1.31 |

It will be noticed that in both orchards there is very little difference between the weight of wood removed in the heavily pruned and moderately pruned plots but that there is quite a difference in size of terminal growth following the prunings. This difference is due to the fact that the greater part of this weight is composed of large limbs and the heartwood in these trees has little or no effect upon their life processes. The amount of new wood removed influences the character of growth, and of this a much larger amount was removed from the heavily than from the moderately pruned blocks.

**Early Bearing and Fruitfulness.** Both orchards in the experiment were old enough to have produced a few fruits when the experiment was begun in 1912. In the Grimes Golden orchard a few scattering fruits were borne, but as the setting of these was in no wise affected by pruning no account was taken of them the first year. In the Lupton orchard a few blooms appeared in 1912 but no fruit set. In 1913 a late freeze destroyed all fruit set in both orchards, and no record regarding it could be secured. In 1914 and 1915 fruit was secured and the amount produced shed considerable light upon the effect of pruning upon fruit production.

Fig. 16.—Fruit Spurs Formed on Lightly Pruned Stayman Winesap Four Years Old.

Contrary to the results in the younger orchards, the first crop secured was not strikingly in favor of light pruning. In fact, but little difference was discernible between any of the plots in 1914, light pruning yielding slightly the more in one orchard and moderate pruning leading by a narrow margin in the other. Both orchards were at an age when active bearing should have begun and undoubtedly the entire loss of the 1913 crop had a decided influence on the formation of fruit buds for 1914. It is not only possible but quite probable that the loss of this crop exerted a greater influence upon fruit bud formation than did the different d

grees of pruning. In 1915 the crops in the two orchards showed marked uniformity in behavior and in each case the heavier pruned plots yielded less than the lighter pruned plots. The combined yields of both years indicate that light pruning is closely correlated with increased fruitfulness. In Table XV, for ease in comparison, yields are shown in terms of percentage, the weight of the yields by the heavily pruned trees being taken as 100.

**TABLE XIII.—Crops in 1914 and 1915. (Lupton Orchard.)**

| Type of Pruning | Year | Apples $2\frac{1}{4}$" and up | | Apples O" - $2\frac{1}{4}$" | | Total No. Per Tree | Total Wt. of Apples Per Tree in lbs. |
|---|---|---|---|---|---|---|---|
| | | No. Per Tree | Wt. Per Tree in lbs. | No. Per Tree | Wt. per Tree in lbs. | | |
| Heavy pruning | 1914 | 11.7 | 3.47 | .6 | .04 | 12.3 | 3.51 |
| Moderate pruning | 1914 | 12.2 | 3.82 | .6 | .06 | 12.8 | 3.88 |
| Light pruning | 1914 | 9. | 2.77 | .77 | .08 | 9.77 | 2.85 |
| Heavy pruning | 1915 | 11.9 | 4.07 | .7 | .14 | 12.6 | 4.21 |
| Moderate pruning | 1915 | 22.9 | 6.98 | 3.9 | .53 | 26.8 | 7.51 |
| Light pruning | 1915 | 47.25 | 13.43 | 9.62 | 1.25 | 56.87 | 14.68 |
| Heavy pruning | Aver- | 11.8 | 3.77 | .65 | .09 | 12.45 | 3.86 |
| Moderate pruning | age, | 17.55 | 5.4 | 2.25 | .3 | 19.8 | 5.7 |
| Light pruning | both years | 28.12 | 8.1 | 5.2 | .66 | 33.22 | 8.76 |

**TABLE XIV.—Crops in 1914 and 1915. (Grimes Golden Orchard.)**

| Type of Pruning | Year | Apples $2\frac{1}{4}$" and up | | Apples O" - $2\frac{1}{4}$" | | Total No. Per Tree | Total Wt. of Apples Per Tree in lbs. |
|---|---|---|---|---|---|---|---|
| | | No. Per Tree | Wt. Per Tree in lbs. | No. Per Tree | Wt. Per Tree in lbs. | | |
| Heavy pruning | 1914 | 476.2 | 132.7 | 55.4 | 8.9 | 529.6 | 141.6 |
| Moderate pruning | 1914 | 378.2 | 106.3 | 45. | 6.5 | 423.2 | 112.8 |
| Light pruning | 1914 | 464.4 | 142.8 | 24. | 3.6 | 488.4 | 146.4 |
| Heavy pruning | 1915 | 163.6 | 63.77 | 4.2 | .57 | 167.6 | 64.34 |
| Moderate pruning | 1915 | 386.6 | 147.94 | 18.6 | 2.64 | 405.2 | 150.58 |
| Light pruning | 1915 | 437.4 | 148.22 | 17.6 | 2.33 | 455. | 150.55 |
| Heavy pruning | Aver- | 319.8 | 98.24 | 29.8 | 4.73 | 348.6 | 102.97 |
| Moderate pruning | age, | 382.4 | 127.12 | 31.8 | 4.57 | 414.2 | 131.69 |
| Light pruning | both years | 450.9 | 145.51 | 20.8 | 2.97 | 471.7 | 148.48 |

**TABLE XV.—Yields in 1914 and 1915 in Percentages.**

LUPTON ORCHARD.

| Type of Pruning | 1914 | 1915 | Average |
|---|---|---|---|
| Heavy | 100 | 100 | 100 |
| Moderate | 110 | 178 | 147 |
| Light | 81 | 349 | 227 |

GRIMES GOLDEN ORCHARD.

| Type of Pruning | 1914 | 1915 | Average |
|---|---|---|---|
| Heavy | 100 | 100 | 100 |
| Moderate | 79 | 234 | 127 |
| Light | 103 | 234 | 145 |

## Effects of Varying Degrees of Dormant Pruning upon Bearing Orchards.

The work in the Boyer orchard was designed to show the effects of pruning upon the vigor and productiveness of trees well launched in their bearing period. As mentioned in the general description of the orchard, the trees were in only a fair condition of vigor at the beginning of the test, but were not in need of what is generally called rejuvenation.

**Character of Annual Terminal Growth.** The terminal growth in this instance behaved in much the same manner as in the younger orchards. There can be no possibility for doubting that heavy pruning produces rank terminal shoots which give the appearance, at least, of strong vigor. No growth measurements were made in this orchard or in the Grimes Golden and Lupton orchards other than to get the average length and thickness of the main terminal extensions. It was thought at the beginning of the experiment that this would make a fair index of tree growth, but the authors know that such is not the case with young trees at any rate for in the Berkeley Springs orchard the lightly pruned trees with comparatively short terminals produced greater total growth. With the present knowledge it can only be surmised that it may also prove a poor index of vigor for bearing trees. These growth measurements together with records of wood annually removed are set forth in Table XVI.

The large amount of wood removed from the heavily pruned Arkansas block is partly due to a few broken limbs that were removed. The Arkansas block responded much more actively to pruning than did the York Imperial block.

**Fruit Production.** In the production of fruit, conclusions must be based upon two crops of Arkansas and one heavy

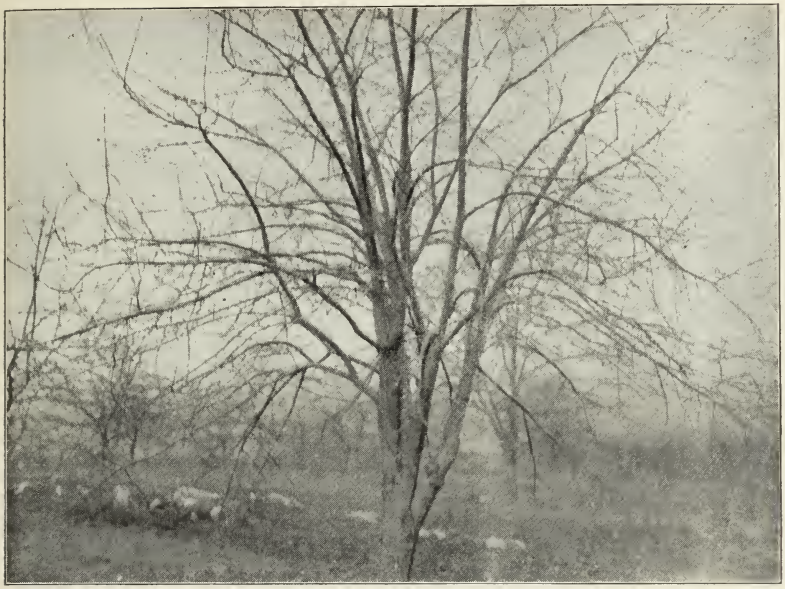

Fig. 17.—Arkansas Tree Before Pruning at the Beginning of the Experiment.

Fig. 18.—Same Tree as Shown in Fig. 17 After Receiving Heavy Dormant Pruning at the Beginning of the Experiment.

TABLE XVI.—Character of Annual Terminal Growth and Amount of Wood Removed.

| | Arkansas | | | York Imperial | | |
|---|---|---|---|---|---|---|
| | Heavy Pruning | Moderate Pruning | Light Pruning | Heavy Pruning | Moderate Pruning | Light Pruning |
| Length in inches, 1911 growth | 4.08 | 4.06 | 4.21 | 4.06 | 3.92 | 4.69 |
| Average growth in inches, 1912-'15 | 9.17 | 8.5 | 7.1 | 5.2 | 4.92 | 4.09 |
| Diameter in inches, 1911 growth | .156 | .149 | .158 | .153 | .152 | .174 |
| Ave. diameter in inches, 1912-'15 growth | .189 | .181 | .17 | .137 | .126 | .128 |
| Wood per tree annually removed in lbs. 1912-'15 | 21.79 | 8.33 | 5.26 | 8.89 | 8.28 | 5.46 |

crop of York Imperial. The latter variety fruited so heavily in 1914 that it produced no fruit at all the following year. As previously mentioned the freeze in 1913 destroyed all the crop in the region of this experiment, and while a light crop badly affected with cedar rust was borne in 1912 no records regarding it were taken since its formation was not affected by the pruning of that year. The yields as recorded in Table XVII show some interesting departures from those of the younger orchards.

TABLE XVII.—Yields of Fruit (Boyer Orchard).

| | Arkansas 1914-'15 Crops | | | York Imperial 1914 Crop | | |
|---|---|---|---|---|---|---|
| | Heavy Pruning | Moderate Pruning | Light Pruning | Heavy Pruning | Moderate Pruning | Light Pruning |
| Bushels apples per tree, diameter over 2¼ in. | 9.53 | 8.05 | 7.73 | 11.9 | 9.95 | 7.9 |
| Bushels apples per tree, diameter under 2¼ in. | .12 | .15 | .16 | 2.12 | 1.99 | 1.25 |
| Total bushels apples per tree | 9.65 | 8.2 | 7.89 | 14.02 | 11.94 | 9.15 |

In this case we have an exact reversal of fruiting habits from those in the younger trees. Both the Arkansas and the York Imperial varieties produced distinctly larger crops on the heavily pruned blocks than on the lightly pruned blocks. This sharp distinction in bearing habits between vigorous young trees and middle-aged trees of subnormal vigor is of interest. ("Middle-aged" is only a relative term. In New York where apples are still in their prime at thirty-five years of age, fifteen-year-old trees would be considered young. In

the Shenandoah valley the commercial orchards generally start their decline at twenty-five to thirty years of age and fifteen to twenty years is truly a middle age.) We know that neglected orchards which have not produced crops of any consequence for years will frequently be greatly benefited and stimulated into fruit production by a heavy pruning. To be sure such trees are abnormal, but it will be noticed that the trees in this orchard made but four inches of terminal growth the year before the experiment began, and that since that time they have averaged from seven to nine inches for one variety and from four to five for the other. This result would indicate that at the beginning the trees were somewhat below normal in vigor, but under better cultural methods their average condition had improved. The writers are of the opinion that, from the standpoint of fruit production, vigorously growing trees would have made a somewhat different response to the treatment than did the ones in the test.

## PART II.—The Effects of Seasonal Pruning upon the Growth and Fruitfulness of Trees of Different Ages.

It is surprising when reviewing the literature on this subject to find how few careful experiments have ever been carried on from which to base our ideas and teachings of the value of summer pruning. The experimental data which we do have lack unity and the results are often contradictory. Batchelor and Goodspeed* of Utah in their summary of a recent publication entitled "The Summer Pruning of a Young Bearing Apple Orchard" have the following to say regarding the summer pruning:

"Trees pruned during dormant period and also during the summer produced a greater annual twig growth than trees pruned during the dormant season only.

"Rubbing the water shoots out of the center of the tree from time to time during the summer had little or no influence on crop production. These shoots are removed more readily and cheaply, however, during this season.

"The summer pruned trees averaged less marketable fruit per tree than either the winter pruned or unpruned trees.

"Summer pruning in this orchard has proven neither profitable nor successful in increasing crop yields.

*Batchelor, L. D. and Goodspeed, W. E., Utah Exp. Sta. Bull. 140, 1915.

"Although the investigation is only in its first stages there seems to be a correlation between regular bearing and summer pruning.

"Summer pruning throughout a period of two months between the third week in June and the third week in August produced much the same results."

Vincent[1] in Idaho found that the average yields for the first four crops of trees given annual summer pruning only were greatly increased in the case of some varieties, while with others this increase was slight and there was very little difference between the yields of summer and winter pruned trees. Wagener showed 111 percent increase in yield where summer pruned, Grimes 52.8 percent, Jonathan 2.4 percent, and Rome 1.6 percent. Color of fruit was much better from the summer pruned trees.

Drinkard[2] working with dwarf trees in Virginia found that, although summer pruning in the latter part of June checked wood growth, fruit bud formation was greatly stimulated by the practice.

Dickens[3], in Kansas, by summer pruning was able to make ten-year-old apple trees bear satisfactory crops. Prior to the summer pruning these trees had borne very little.

Papers on "The Summer Pruning of Fruit Trees" by fruit growers and horticulturists of the Royal Horticultural Society[4] in England showed that, while there was a difference of opinion as to the value of summer pruning, as a whole the consensus of opinion was that summer pruning was uncertain in its effects and that the operation was of doubtful practicability. Much depended on soil, climate, moisture, varieties, stocks, and time of the operations.

Opinions of 166 fruit growers and gardeners in the British Isles, compiled by the Gardener's Chronicle[5] show that while 140 had from fair to very good results from summer pruning of pome fruits, 26 were doubtful of its practicability and value.

Spencer Pickering[6] of the Woburn Experimental Farm, England, reported in Science Progress that, although the evidence was still inconclusive, ordinary annual summer pruning had caused no appreciable results in fruiting or vigor of the apple and that pinching, bending, etc., were uncertain and depended on weather conditions following the operations.

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[1] Vincent, C. C., Idaho Agr. Exp. Sta., Bull. 84, p. 25, 1915.
[1] Vincent, C. C., Rept. Proc. Fruit Products Congress, Spokane, Wash., Nov. 16-21, 1914, pp. 5-6.
[2] Drinkard, A. W., Virginia Agr. Exp. Sta., Tech. Bull. 5, pp. 111-12, 1915.
[3] Dickens, A., Kansas Sta. Agr. Exp. Sta., Bull. 136, 1906.
[4] The Journal Royal Horticultural Society, Vol. 33, Part 2, pp. 487-499, 1908.
[5] The Gardener's Chronicle, Third Series, Vol. 41, pp. 400-403; 406-7, 1907.
[6] Science Progress, Vol. 7, No. 27, p. 397, 1913.

It can be seen from the preceding statements that the results from summer pruning are not always similar. Several different factors, such as the vigor of the tree, the time of pruning, the character of the pruning, the season, the soil, and many others enter in to influence the results.

It is doubtful if any very general recommendations can ever be made regarding summer pruning and although the authors realize that criticisms can be made on their work, it is presented with the hope that it will add a little more definite information on this subject.

### Outline and Plans of the West Virginia Experiments.

Summer pruning alone and in combination with winter pruning was carried on in all of the orchards previously described, except the Berkeley Springs orchard. Table I shows the various combinations that were used.

The character of the summer pruning only was about the same as was that of the moderate dormant pruning, the only difference being the date on which it was done. The character of the summer pruning has been described on page seven. In the case of the winter and summer pruning, the trees were headed back in the winter and about one-half of the wood was thinned out. In the summer time, the other half of the wood was thinned out and the suckers were removed. In the case of the repeated summer pruning it was attempted to do about the same amount of pruning at each date. The sum of these two prunings made about the same as the moderate dormant pruning and left the trees pruned in about the same manner as regards shape, etc. Dates at which these prunings were made are shown on page seven.

### The Effects of Seasonal Pruning upon the First Five Years' Growth of Trees.

Data on this phase of the work were secured entirely from the Sheets orchard. As suggested on page four, conditions in this orchard were not as uniform as we wished to have them. It was necessary to discard several of the original trees due to differences in their ages, and as a result of this only twenty-three trees were left in the experiment. The varieties of York Imperial, Grimes, and Rome were included in this test. In as much as all of the varieties responded similarly, the results have been grouped for comparison in the following tables. The summer pruning on these trees was done each year during the first week of July. Varying degrees of dormant pruning were done as previously described. Very little yearly data were secured on these trees with the exception of that of the

past year, as the main object was to note the effect of the pruning upon fruitfulness.

**Character of the Annual Terminal Growth and Amount of Wood Removed.** In order to get some data regarding the effect of several years' annual seasonal pruning upon terminal growth, several measurements were made upon all the trees at the close of the growth in 1915. The experiment had then been running for five years.

**TABLE XVIII.—Average Length of Terminal Growth and Weight of Wood Removed per Tree.**

| Method of Pruning | No. of Trees | Av. Length of Terminal Growth in Inches 1915 | Weight Removed in Lbs. per Tree | | | |
|---|---|---|---|---|---|---|
| | | | 1913 | 1914 | 1915 | Three-Year Average |
| Heavy dormant | 7 | 23.5 | 2.57 | 2.26 | 1.36 | 2.06 |
| Moderate dormant | 5 | 13.5 | 2.25 | 1.6 | .68 | 1.51 |
| Light dormant | 6 | 9.9 | 1.46 | 1.5 | .54 | 1.17 |
| Summer pruning | 5 | 13.1 | 3.6 | 2.45 | 2.1 | 2.71 |

These results show that the trees pruned heavily in the dormant season made by far the longest average terminal growth. The summer pruned trees made a longer growth than the trees pruned lightly in the dormant season, but did not make quite as much growth as did the moderately pruned trees.

It is seen that the three-year average weight of wood removed per tree was largest in the case of the summer pruned trees. This, however, is not a very exact or fair comparison as a large amount of this weight was made up of leaves. The actual pruning of the trees was about comparable to that of the moderately pruned ones.

**Total Length of Annual Growth.** In 1915 the total length of new longitudinal growth produced on all of the trees was measured. These measurements give us some idea of the vigor of the trees and are an indication of the volume of new wood produced.

**TABLE XIX.—Average Length per Tree of Longitudinal Growth in 1915.**

| | Heavy Dormant | Moderate Dormant | Light Dormant | Summer Pruning |
|---|---|---|---|---|
| Total longitudinal growth produced in feet | 216 | 187 | 188 | 120 |

Table XIX shows that summer pruning has checked decidedly the growth of the trees as regards total amount of new wood produced.

**Circumference of Trunks and Size and Form of Trees.** Although Table XVIII and Table XIX show that summer pruning has checked the growth of the trees as far as terminal and total annual growths are concerned, it is interesting to know what effect the summer pruning had upon the stockiness of the trees, and their size, and form. Measurements regarding these points were taken on all the trees in 1915.

**TABLE XX.—Circumference of Trunks and Height and Width of Trees.**

| Method of Pruning | No. of Trees | Circumference of Trunks in Inches | Av. Height of Tree in Feet | Av. Width of Tree in Feet |
|---|---|---|---|---|
| Heavy dormant | 7 | 8.46 | 8.55 | 4.83 |
| Moderate dormant | 5 | 9.62 | 9.73 | 6.17 |
| Light dormant | 6 | 9.91 | 10.5 | 7.1 |
| Summer pruning | 5 | 9.2 | 9.7 | 6.3 |

It can be seen from Table XX that the trees pruned moderately or lightly during the dormant season have larger trunks than do the summer pruned ones. In the case of the continued heavy dormant pruning, which method we do not recommend, the trunks are smaller than those of the summer pruned trees. As regards the height and width of the trees, it can be seen that the summer pruned trees are very similar to the moderate dormant pruned trees in this respect. The summer pruned trees are larger than the heavy dormant pruned ones, but smaller than the light dormant pruned trees.

**Early Bearing.** From Tables XVIII, XIX, and XX it can be seen that the summer pruned trees made nearly as long average terminal growths as the moderate dormant pruned ones, but that the total amount of longitudinal growth was less and that the trunks of the trees were smaller. The height and width of the trees were about the same in these two cases. It is interesting now to know what influence summer pruning has had upon early bearing. Although only a few fruits have been produced up to this time, blooming data have been secured each year and also the percentage of fruit buds for 1916.

**TABLE XXI.—Effect of Pruning upon Early Bearing.**

| Method of Pruning | Bloom Clusters per Tree in 1914 | Fruits per Tree in 1914 | Bloom Clusters per Tree in 1915 | Fruits per Tree in 1915 | | Percent Fruit Buds per Tree 1916 |
|---|---|---|---|---|---|---|
| | | | | Number | Wt. (lbs) | |
| Heavy dormant | .14 | 0 | 1.86 | .7 | .25 | 3.7 |
| Moderate dormant | 3.4 | .2 | 40. | 12.2 | 3.35 | 20.0 |
| Light dormant | 15.5 | 2.0 | 175. | 24. | 6.64 | 38.0 |
| Summer pruning | 0 | 0 | 39. | .33 | .08 | 10.4 |

Table XXI shows that the light dormant pruning caused the trees to come into bearing earlier and to produce considerably more fruit than did any of the other methods of pruning. The summer pruned trees did not bear as early nor did they produce as much fruit in 1914 and 1915 as did any of the modifications of dormant pruning. The percentage of fruit buds set for the 1916 crop on the moderate and light dormant pruned trees greatly exceeds that for the summer pruned trees. **In this experiment, summer pruning has checked tree growth and has delayed and decreased fruit production.**

## Effects of Seasonal Pruning upon Orchards Just Attaining Bearing Age.

Information upon this phase of the work was secured from the Lupton and Grimes Golden orchards. The variety used in each of these orchards was the York Imperial. Forty-five trees of five each in a plot were used in the Grimes Golden orchard, while there were ninety trees of ten in a plot in the

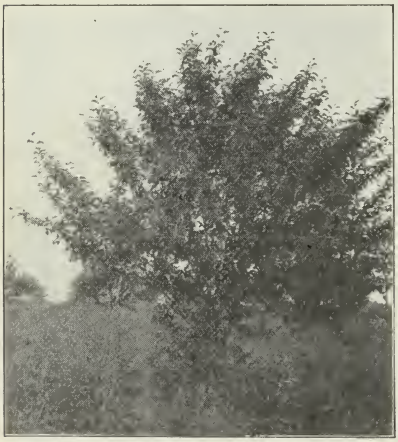

Fig. 19.—York Imperial Tree in Lupton Orchard Before Summer Pruning.

Fig. 20.—Same Tree as Shown in Fig. 19 After Summer Pruning.

Lupton orchard. It was necessary for various reasons to discard certain trees from each orchard during the experiment and as a result there were left 37 trees in the Grimes Golden orchard and 88 in the Lupton orchard which are here reported on. Trees in the Grimes Golden orchard were seven years old at the beginning of the experiment, while those in the Lupton orchard were six. In these orchards varying degrees of dor-

mant pruning, dormant and summer pruning, and summer pruning only were carried on.

By referring to Table I and to the discussion under "Definition of Treatment" on page seven, a fuller explanation of the experiments can be found.

**Character of Annual Terminal Growth and Weight of Wood Removed.** The length and diameter of the terminal growth* of each tree in the experiment were taken in the spring of 1911, in order to show the condition of the trees at the beginning of the experiment. These measurements have been continued each year until the present time and the averages for the years 1912 to 1915 inclusive are shown in the accompanying table. The amount of wood removed at each pruning has been weighed and the weights are likewise shown.

**TABLE XXII.—Character of Annual Terminal Growth and Weight of Wood Removed (Lupton Orchard).**

| Method of Pruning | Average Length of Terminal Growth | | Average Diameter of of Terminal Growth | | Weight of Wood Removed in lbs. |
|---|---|---|---|---|---|
| | 1911 | 1912-'15 | 1911 | 1912-'15 | 1912-'15 |
| Heavy dormant | 7.87 | 15.87 | .159 | .218 | 3.87 |
| Moderate dormant | 7.30 | 10.74 | .156 | .181 | 3.39 |
| Light dormant | 7.75 | 8.37 | .166 | .166 | 1.31 |
| Heavy dormant and early summer | 8.65 | 15.99 | .172 | .212 | 4.83 |
| Moderate dormant and early summer | 8.50 | 13.45 | .18 | .193 | 8.50 |
| Early summer only | 8.29 | 10.48 | .174 | .177 | 7.05 |
| Midsummer only | 7.31 | 8.83 | .17 | .17 | 5.87 |
| Repeated summer | 7.78 (1913) | 8.55 (1914-15) | .172 | .167 | 6.32 |
| Ringing | 9.86 | 6.63 | .174 | .157 | 4.69 |

A study of Table XXII shows that in the Lupton orchard where early summer pruning has been used in connection with heavy and moderate dormant pruning (plots four and five), the length and diameter of the terminal growth have been slightly increased over plots one and two where no summer pruning was used. However, this slight increase may well be due to chance, as it will be noticed that where early summer pruning alone was used (plot six) the resulting terminal growth was neither as long nor as thick as was that resulting where only the moderate or heavy dormant pruning was used. Neither was this beneficial effect noted in the Grimes Golden orchard.

*Ten measurements were made on each tree in the experiment.

In the plots where midsummer or repeated summer prunings were given, both the length and thickness of the resulting terminal growths were considerably reduced. Ringing also had a decidedly detrimental effect upon the resulting growth.

**TABLE XXIII.—Character of Annual Terminal Growth and Weight of Wood Removed (Grimes Golden Orchard).**

| Method of Pruning | Average Length of Terminal Growth | | Average Diameter of Terminal Growth | | Weight of Wood Removed in lbs. 1912-'15 |
|---|---|---|---|---|---|
| | 1911 | 1912-'15 | 1911 | 1912-'15 | |
| Heavy dormant | 12.41 | 14.79 | .214 | .215 | 8.37 |
| Moderate dormant | 14.42 | 12.68 | .211 | .18 | 7.81 |
| Light dormant | 15. | 11.36 | .22 | .172 | 3.78 |
| Heavy dormant and early summer | 14.5 | 13.62 | .214 | .205 | 17.09 |
| Moderate dormant and early summer | 13.26 | 10.71 | .199 | .162 | 7.68 |
| Early summer only | 14.72 | 12.18 | .214 | .182 | 10.59 |
| Midsummer only | 13.59 | 11.31 | .202 | .169 | 11.36 |
| Repeated summer | 14.91 | 11.56 | .219 | .174 | 12.01 |
| Ringing | 16.96 | 9.95 | .212 | .152 | 9.54 |

In the Grimes Golden orchard (Table XXIII) heavy or moderate dormant pruning caused a larger terminal growth than any of the other treatments. In this case, the early summer pruning, instead of being beneficial when used in connection with the heavy and moderate dormant pruning, seemed to be detrimental. In this orchard as in the Lupton orchard, early summer pruning alone was not as beneficial as either the heavy or moderate dormant pruning when used alone. Although the midsummer and repeated summer pruning did not appear to retard the terminal growth as much in this orchard as in the Lupton orchard, still they noticeably retarded growth when compared to dormant pruning only. Ringing in this orchard seriously affected terminal growth as it did in the Lupton orchard.

Although trees pruned in the summer appear to have had more weight removed than did the dormant pruned ones, a large proportion of this weight was leaves. The summer pruning, as previously stated, was about the same in amount and degree as the moderate dormant pruning.

**Increase in Trunk Circumference.** At the close of the 1914 season the circumference of the tree trunks half way between the head and the ground was measured on each tree in the Grimes Golden orchard. These same trees were measured

at the close of the 1915 season in order to find if the seasonal pruning had exerted any influence on the increase in trunk measurement.

**TABLE XXIV.—Increase in One Year in Circumference of Trunks Due to Seasonal Pruning.**

| Method of Pruning | Increase in Trunk Circumference in Inches |
|---|---|
| Heavy dormant | 2.2 |
| Moderate dormant | 2.15 |
| Light dormant | 2.15 |
| Heavy dormant and early summer | 2. |
| Moderate dormant and early summer | 2. |
| Early summer | 2.2 |
| Midsummer | 1.95 |
| Repeated summer | 1.88 |
| Ringing | 1.95 |

The results show that midsummer and repeated summer pruning retard the growth of the tree trunks in much the same way as they did the terminal growth.

When early summer pruning was used in connection with heavy and moderate dormant pruning, the increase in trunk was not as large as in those cases where the dormant pruning was used alone. This is similar to the effects produced on terminal growth as shown in Tables XXII and XXIII. When used alone early summer pruning gave satisfactory increase.

**Effect of Seasonal Pruning on Size of Leaves, Color of Foliage, and Total Amount of Foliage.** Differences in foliage were so plainly noticeable in the different pruning plots at picking time (October, 1915) that careful measurements and counts were made of the leaves on the different trees in the several plots. In securing the length and width of the leaves, fifty were selected from each tree and measured. These measurements for all trees in each block were then averaged and the results taken as the average size of leaves for that block. The area of the leaf was found by multiplying the length by seven-tenths of the width. In finding the total number of leaves per tree, one tree was taken as representing the ideal in size and denseness of foliage and considered as 100 in size and number of leaves. The total number of leaves on this tree was then counted for use as a basis in comparing the other trees. All of the remaining trees were then compared to the ideal tree in size and in number of leaves and given a certain percentage rating. By comparing these percentages to the ideal we were able to get quite accurately the total number of leaves per tree. The total number of leaves found for all trees in each plot was then averaged to find the average num-

ber of leaves per tree in each plot. By multiplying the average number of leaves per tree by the average area per leaf, the total average area of leaf surface per tree in each plot was obtained.

**TABLE XXV.—Size of Leaves and Total Area of Leaves per Tree as Affected by Seasonal Pruning (Lupton Orchard).**

| Method of Pruning | Ave. Length of Leaves in Inches | Ave. Width of Leaves in Inches | Area of Leaves in Sq. Inches | Total No. of Leaves Per Tree | Total Area per Tree Sq. Ft. | Rank |
|---|---|---|---|---|---|---|
| Heavy dormant | 2.60 | 1.52 | 2.77 | 31,755 | 610.8 | 1 |
| Moderate dormant | 2.46 | 1.38 | 2.37 | 26,263 | 432.2 | 4 |
| Light dormant | 2.3 | 1.3 | 2.1 | 28,718 | 418.7 | 5 |
| Heavy dormant and early summer | 2.48 | 1.54 | 2.67 | 28,290 | 524.5 | 2 |
| Mod. dormant and early summer | 2.29 | 1.33 | 2.13 | 30,473 | 450.7 | 3 |
| Early summer | 2.34 | 1.39 | 2.28 | 24,253 | 384. | 6 |
| Midsummer | 2.36 | 1.32 | 2.18 | 18,760 | 284. | 9 |
| Repeated summer | 2.28 | 1.3 | 2.07 | 20,689 | 297.4 | 8 |
| Ringing | 2.26 | 1.27 | 1.91 | 24,588 | 325.4 | 7 |

**TABLE XXVI.—Size of Leaves and Total Area of Leaves per Tree as Affected by Seasonal Pruning (Grimes Golden Orchard).**

| Method of Pruning | Ave. Length of Leaves in Inches | Ave. Width of Leaves in Inches | Area of Leaves in Sq Inches | Total No. of Leaves per Tree | Total Area per Tree Sq. Ft. | Rank |
|---|---|---|---|---|---|---|
| Heavy dormant | 3.57 | 2.0 | 4.99 | 36,309 | 1143.8 | 1 |
| Moderate dormant | 3.51 | 1.7 | 4.18 | 31,403 | 911.5 | 2 |
| Light dormant | 3.1 | 1.62 | 3.52 | 26,987 | 659.6 | 4 |
| Heavy dormant and early summer | 3.23 | 1.69 | 3.82 | 29,931 | 794.0 | 3 |
| Mod. dormant and early summer | 3.17 | 1.7 | 3.77 | 20,117 | 526.6 | 6 |
| Early summer | 2.73 | 1.6 | 3.06 | 21,589 | 458.7 | 8 |
| Midsummer | 2.8 | 1.47 | 2.88 | 24,042 | 480.8 | 7 |
| Repeated summer | 2.54 | 1.36 | 2.42 | 17,787 | 298.9 | 9 |
| Ringing | 2.94 | 1.64 | 3.38 | 23,061 | 541.2 | 5 |

Tables XXV and XXVI give in tabular form the size of leaves per tree, total number of leaves per tree, total leaf area per tree, and the rank of each plot based upon the total leaf area per tree. It is plainly noticeable that the trees pruned during the dormant season had by far the larger leaves and the greater number of leaves. In contrast to this the trees

which had been summer pruned only produced the smaller leaves and ranked lower regarding total number of leaves and area of foliage. Early summer pruning in connection with dormant pruning retarded leaf development somewhat and when used alone did not produce as good results as did the moderate dormant pruning. These results are similar to those found in Tables XXII, XXIII, and XXIV where its effects on terminal growth and trunk increase were noted. It will be noticed that, although the first five plots in each orchard vary a little in their order of rank, they all place ahead of early summer pruning. The next three plots of summer pruning all fall in the lowest ranks.

**Color of Foliage.** Differences in color of the foliage were likewise very noticeable at this date (October) but earlier in the season no striking differences were discernible. In all cases those trees which had been pruned during the dormant season or with some modification of the dormant season pruning had a darker green and healthier looking foliage. The leaves of the midsummer and repeated summer pruned trees had turned a yellowish green color and presented a much less vigorous appearance.

It is impossible to explain definitely these striking differences in foliage. We know that the leaves, under the action of chlorophyll, transform the raw materials, brought them from the roots, into plant food. It is also understood that some of this plant food is then stored in the main branches and smaller twigs where the tree can draw upon it in the future. By summer pruning not only are large numbers of these active leaves removed but probably much stored food in the limbs and twigs is also removed. It is very probable that by destroying many of the manufacturing parts of the plant and removing some stored up food that these effects will be noticed in the reduced leaf area the following year.

The change in color of the foliage is still harder to explain. It may be that due to the weaker condition of the summer pruned trees, as evidenced by lessened terminal growths, small tree trunks, less foliage, etc., the leaves of the summer pruned trees had passed through their cycle of activity earlier than the leaves on the dormant pruned, more healthy trees. These activities were probably followed by a breaking down of the chlorophyll which would be reflected by a diminishing of the dark green color.*

**Early Bearing and Fruitfulness.** Having seen that summer pruning has acted as a check on the growth and develop-

*In future investigations on this subject it would be highly advantageous to make quantitative determinations of the chlorophyll present in the leaves.

ment of young trees just coming into bearing, let us see what effect summer pruning has had upon the first crop of such trees. As stated on page twenty-four, there were a few blooms on each orchard in 1912, following the year that the experiment was begun. As the setting of these was not affected by pruning and since so few of them did set, no account of them was taken. Unfortunately, a late freeze in 1913 destroyed all fruit set in both orchards, so no record of the crop could be secured in that year. However, in 1914 and 1915 there was fruit in both orchards and some interesting data were secured concerning the effects of seasonal pruning on the first crop of young orchards.

TABLE XXVII.—Crop in 1914 (Lupton Orchard).

| Method of Pruning | Apples 2¼" and Up | | Apples 0 - 2¼" | | Total Number per Tree | Total Wt. of Apples per Tree in lbs. |
|---|---|---|---|---|---|---|
| | No. per Tree | Wt. per Tree, lbs. | No. per Tree | Wt. per Tree, lbs. | | |
| Heavy dormant | 11.7 | 3.47 | .6 | .04 | 12.3 | 3.51 |
| Moderate dormant | 12.2 | 3.82 | .6 | .06 | 12.8 | 3.88 |
| Light dormant | 9. | 2.77 | .77 | .08 | 9.77 | 2.85 |
| Heavy dormant and early summer | 2.4 | .77 | .3 | .03 | 2.7 | .81 |
| Mod. dormant and early summer | 16.4 | 5.45 | 1.1 | .12 | 17.5 | 5.57 |
| Early summer | 11.6 | 3.62 | .9 | .11 | 12.5 | 3.73 |
| Midsummer | 5.4 | 1.73 | .5 | .06 | 5.9 | 1.79 |
| Repeated summer | 5.9 | 2.15 | .3 | .03 | 6.2 | 2.18 |
| Ringing | 62.5 | 17.56 | 7.25 | 1.00 | 69.75 | 18.56 |

TABLE XXVIII.—Crop in 1915 (Lupton Orchard).

| Method of Pruning | Apples 2¼" and up | | Apples 0 - 2¼" | | Total Number per Tree | Total Wt. of Apples per Tree in lbs. |
|---|---|---|---|---|---|---|
| | No. per Tree | Wt. per Tree, lbs. | No. per Tree | Wt. per Tree, lbs. | | |
| Heavy dormant | 11.9 | 4.07 | .7 | .14 | 12.6 | 4.21 |
| Moderate dormant | 22.9 | 6.98 | 3.9 | .53 | 26.8 | 7.51 |
| Light dormant | 47.25 | 13.43 | 9.62 | 1.25 | 56.87 | 14.68 |
| Heavy dormant and early summer | 5.7 | 1.76 | .7 | .08 | 6.4 | 1.84 |
| Mod. dormant and early summer | 24.6 | 7.51 | 3.4 | .54 | 28.0 | 8.05 |
| Early summer | 20.3 | 6.06 | 3.3 | .47 | 23.6 | 6.53 |
| Midsummer | 10.3 | 3.36 | 1.3 | .16 | 11.6 | 3.52 |
| Repeated summer | 11.5 | 3.24 | 2.4 | .29 | 13.9 | 3.53 |
| Ringing | 1.6 | .56 | .4 | .05 | 2.0 | .61 |

TABLE XXIX.—Average Crops in 1914 and 1915 (Lupton Orchard).

| Method of Pruning | Apples 2¼" and up | | Apples 0 - 2¼" | | Total Number per Tree | Total Wt. of Apples per Tree in lbs. |
|---|---|---|---|---|---|---|
| | No. per Tree | Wt. per Tree, lbs. | No. per Tree | Wt. per Tree, lbs. | | |
| Heavy dormant | 11.8 | 3.77 | .65 | .09 | 12.45 | 3.86 |
| Moderate dormant | 17.55 | 5.4 | 2.25 | .3 | 19.8 | 5.7 |
| Light dormant | 28.12 | 8.1 | 5.19 | .66 | 33.32 | 8.76 |
| Heavy dormant and early summer | 4.05 | 1.26 | .5 | .05 | 4.55 | 1.32 |
| Mod. dormant and early summer | 20.5 | 6.48 | 2.25 | .33 | 22.75 | 6.81 |
| Early summer | 15.95 | 4.84 | 2.1 | .29 | 18.05 | 5.18 |
| Midsummer | 7.85 | 2.54 | .9 | .11 | 8.75 | 2.61 |
| Repeated summer | 8.7 | 2.69 | 1.35 | .16 | 10.05 | 2.85 |
| Ringing | 32.05 | 9.06 | 3.82 | .52 | 35.87 | 9.58 |

TABLE XXX.—Crop in 1914 (Grimes Golden Orchard).

| Method of Pruning | Apples 2¼" and up | | Apples 0 - 2¼" | | Total Number Apples per Tree | Total Wt. of Apples per Tree in lbs. |
|---|---|---|---|---|---|---|
| | No. per Tree | Wt. per Tree, lbs. | No. per Tree | Wt. per Tree, lbs. | | |
| Heavy dormant | 476.2 | 132.7 | 55.4 | 8.9 | 529.6 | 141.6 |
| Moderate dormant | 378.2 | 106.3 | 45. | 6.5 | 423.2 | 112.8 |
| Light dormant | 464.4 | 142.8 | 24. | 3.6 | 488.4 | 146.4 |
| Heavy dormant and early summer | 46.0 | 18.5 | 8. | 1.12 | 54. | 19.62 |
| Mod. dormant and early summer | 228.5 | 77.5 | 9.5 | 1.25 | 238.0 | 78.75 |
| Early summer | 76.6 | 28.3 | 2. | .52 | 78.6 | 28.82 |
| Midsummer | 13.0 | 4.4 | 1.8 | .2 | 14.8 | 4.6 |
| Repeated summer | 38.5 | 16.0 | .75 | .09 | 39.25 | 16.09 |
| Ringing | 661.4 | 150.4 | 150.6 | 18.20 | 812.0 | 168.6 |

TABLE XXXI.—Crop in 1915 (Grimes Golden Orchard).

| Method of Pruning | Apples 2¼" and up | | Apples 0 - 2¼" | | Total Number Apples per Tree | Total Wt. of Apples per Tree in lbs. |
|---|---|---|---|---|---|---|
| | No. per Tree | Wt. per Tree, lbs. | No. per Tree | Wt. per Tree, lbs. | | |
| Heavy dormant | 163.4 | 63.77 | 4.2 | .57 | 167.6 | 64.34 |
| Moderate dormant | 386.6 | 147.94 | 18.6 | 2.64 | 405.2 | 150.58 |
| Light dormant | 437.4 | 148.22 | 17.6 | 2.33 | 455.0 | 150.55 |
| Heavy dormant and early summer | 334.0 | 97.50 | 0.0 | 0.0 | 334. | 97.50 |
| Mod. dormant and early summer | 265.5 | 69.74 | 18.5 | 2.09 | 284. | 71.83 |
| Early summer | 222.4 | 66.02 | 22.6 | 3.39 | 245. | 69.41 |
| Midsummer | 236.0 | 58.34 | 44.6 | 6.19 | 284.6 | 64.53 |
| Repeated summer | 211.25 | 59.34 | 22.25 | 3.68 | 233.5 | 63.02 |
| Ringing | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**TABLE XXXII.—Average Crops in 1914 and 1915. (Grimes Golden Orchard).**

| Method of Pruning | Apples 2¼" and up | | Apples 0 - 2¼" | | Total Number Apples per Tree | Total Wt. of Apples per Tree in lbs. |
|---|---|---|---|---|---|---|
| | No. per Tree | Wt. per Tree lbs. | No. per Tree | Wt. per Tree, lbs. | | |
| Heavy dormant | 319.8 | 98.24 | 29.8 | 4.73 | 348.60 | 102.97 |
| Moderate dormant | 382.4 | 127.12 | 31.8 | 4.57 | 414.2 | 131.69 |
| Light dormant | 450.9 | 145.51 | 20.8 | 2.96 | 471.7 | 148.48 |
| Heavy dormant and early summer | 190. | 58.00 | 4.0 | .56 | 194.0 | 58.56 |
| Mod. dormant and early summer | 247. | 73.62 | 14.0 | 1.67 | 261.0 | 75.29 |
| Early summer | 149.5 | 47.16 | 12.3 | 1.95 | 161.8 | 48.96 |
| Midsummer | 124.5 | 31.37 | 25.20 | 3.19 | 149.7 | 34.57 |
| Repeated summer | 124.87 | 37.67 | 11.5 | 1.88 | 136.37 | 39.55 |
| Ringing | 330.7 | 75.20 | 75.30 | 9.10 | 403.00 | 84.30 |

Although the 1914 crop in the Lupton orchard was very light (Table XXVII) still the results were uniform enough to indicate the effect of seasonal pruning on fruitfulness. It will be seen in this case that the dormant pruned trees yielded about twice as much fruit as those trees pruned in midsummer, or repeated summer. The early summer pruning alone seemed to give satisfactory results, but in connection with dormant pruning its effects were rather contradictory. The following year, the trees under the different pruning methods responded in practically the same manner as they had the previous year. Table XXVIII shows that the yield of fruit from the dormant pruned trees far exceeded that from the summer pruned ones. In Table XXIX the yields for the two crops in the Lupton orchard have been averaged and recorded. A study of this table emphasizes the points just brought out. Midsummer or repeated summer pruning has seriously retarded crop production. Early summer pruning, while evidently not as detrimental as the later prunings, does not produce as satisfactory results as moderate or light dormant pruning.

In the Grimes Golden orchard, where larger crops were produced, practically the same results were obtained as in the Lupton orchard. Tables XXX and XXXI show the yields from the different plots in 1914 and 1915, while Table XXXII gives the average yields for these two years. In this table, it will be seen that the average weight of fruit from the dormant pruned plots was 127.71 pounds per tree; from the dormant and early summer pruned plot, 66.92 pounds per tree;

and from the summer pruned plots, 41.02 pounds per tree. In both orchards the light dormant pruning gave the best results as regards fruit production.

For ease in comparison, the yields of the dormant pruned trees, the dormant and summer pruned trees, and the ones pruned in the summer time only have been averaged for each orchard, and are shown in terms of percentages. The weight of fruit from the dormant pruned trees is taken as 100.

TABLE XXXIII.—Yields of 1914 and 1915 in Percentages.

LUPTON ORCHARD.

| Type of Pruning | 1914 | 1915 | Average |
|---|---|---|---|
| Dormant pruned | 100. | 100. | 100. |
| Dormant and summer pruned | 93.5 | 56.1 | 66.6 |
| Summer pruned | 75.2 | 51.5 | 58.2 |

GRIMES GOLDEN ORCHARD.

| Type of Pruning | 1914 | 1915 | Average |
|---|---|---|---|
| Dormant pruned | 100. | 100. | 100. |
| Dormant and summer pruned | 36.8 | 69.5 | 52.4 |
| Summer pruned | 12.3 | 53.9 | 32.1 |

These results are very similar to those found by Batchelor and Goodspeed in Utah[1]. These authors, in reporting the results of four years' pruning experiments on young bearing Jonathan trees, state that the summer pruned plots averaged 191 pounds of fruit less per tree for the four years than did similar trees pruned in the dormant season. The summer pruned plots also averaged 112 pounds of fruit less per tree than the unpruned trees. Their reports on similarly pruned Gano trees show that the summer pruned trees produced 112 pounds per tree less than the dormant pruned ones and 219 pounds per tree less than unpruned trees.

**Our experiments on young trees bearing their first crops thus show that summer pruning has reduced both vigor and fruitfulness.**

## The Effects of Ringing on the Growth and Fruitfulness of Young Apple Trees.

On May 31, 1913, seven trees in the Lupton orchard and five in the Grimes Golden orchard were ringed. At that time, the foliage was well developed and the sap was flowing freely. These trees were pruned at the time of ringing in 1913 and received a light to moderate pruning before growth started

*Batchelor, L. D. and Goodspeed, W. E., Utah Agr. Exp. Sta., Bull. 140.

in 1914 and 1915. In the operation of ringing a small circular band of bark extending through the cortex and bast about three-fourths of an inch in width was removed from each tree at about four inches above the level of the ground. Theoretically, ringing is not supposed to prevent the passage of the unassimilated sap from the roots to the leaves, but does prevent the distribution of the assimilated sap below the place ringed. By causing this large amount of food material to be stored in the upper parts of the tree, the formation of many more fruit buds is supposed to take place. With a view of obtaining some data as to the effects of ringing on the vigor and fruitfulness of young bearing apple trees, this experiment was started.

**Effect of Ringing on Terminal Growth.** By referring to Table XXII and Table XXIII the effect of ringing on the terminal growth in the two orchards can be seen. It will be noticed in both orchards that the terminal growth was as vigorous as any at the beginning of the experiment. The ringing seriously retarded this growth in the next two years. In both orchards the ringed trees made a poorer terminal growth than did any of the other plots. In the Lupton orchard, the terminal growth on the heavy dormant pruned trees was more than twice as vigorous as that on the ringed trees. Ringing in this case certainly reduced the vigor of the trees.

**Effect of Ringing on Trunk Circumference.** The increase in trunk circumference in the Grimes Golden orchard was taken for the year 1914. In Table XXIV it will be seen that the ringing acted as a check in trunk development when compared with the dormant pruning. The trunks of the ringed trees increased at the same rate as did those pruned in midsummer.

**Effect of Ringing on Size of Leaves and Total Area of Leaf Surface.** By referring to Tables XXV and XXVI the effect of ringing on foliage development can be seen. In the case of the ringed trees in the Lupton orchard, the leaves were shorter and narrower and had less area than did those in any of the other plots. These trees had slightly more leaves per tree than did the summer pruned ones, but considerably fewer than the dormant pruned trees. The ringed plot ranked seventh as regards total leaf area per tree. In the case of the Grimes Golden orchard, ringing again acted as a check to leaf development. Although in this case the leaves were slightly larger than those on the summer pruned tree, still they were considerably smaller than those on the dormant

pruned trees. This weakened appearance of the tree as regards color and amount of foliage was very plainly noticeable. In fact, the trees appeared more sickly than the figures show.

**Effect of Ringing on Fruitfulness.** Tables XXVII to XXIX show the effect of ringing on fruitfulness in the Lupton orchard. It will be seen that in 1914, the year following the ringing, the ringed trees bore larger amounts of fruit than did those in any of the other plots. However, the following year, 1915, these same trees bore practically no fruit, while the other plots produced good crops.

Similar results were secured in the Grimes Golden orchard only in a more striking degree. Tables XXX to XXXII show that while the ringed trees bore the largest crops in 1914, they produced no fruit whatever in 1915. It will also be noticed that the apples were undersized and poor in 1914. It should be noted here that the season of 1914 was very dry. This may partially account for the lack of development of the fruit of that year and for the depleted tree vigor that was so apparent. Although the ringed trees in both orchards have appeared to regain their vigor somewhat during the present year (1916) still they are far from being as vigorous as the dormant pruned trees and are bearing practically no fruit buds. Three trees ringed in this orchard in 1912 responded in the same manner as those just described. All bore well in 1913 but produced practically nothing in 1914 and 1915.

From the results of our observations, ringing plainly checks the vigor of the tree for at least three years and although it has been successful in causing trees to bear the year following the operation, this bearing has not been established as a habit.

**Experiments on Ringing Apples in Other States.** Howe of the Geneva New York Station[1] in his summary on "Ringing Fruit Trees" states that under certain conditions ringing may induce and possibly increase fruitfulness in apples, but it rarely has these favorable effects on other fruits. He also states that only young and very vigorous apple trees, possibly now and then pear and cherry trees, can survive ringing and that even with these fruits the compensating gains seldom offset the injury to the trees. He found that the general effect of ringing on the roots of the trees was to decrease their size and number and lessen their vigor.

Drinkard in Virginia[2] working with young dwarf apples concluded that ringing at different seasons when accompanied

[1] Howe, G. H., N. Y. Agr. Exp. Sta., Bull. 391.
[2] Drinkard, A. W. Jr., Va. Agr. Exp. Sta., Tech. Bull. 5.

or preceded by spring pruning of the branches produced no noticeable stimulation of fruit bud development, but that when ringing was done at the time the foliage was fully developed in the absence of spring pruning, fruit bud development was uniformly increased. In this case, although the growth of the trees was good, he states that the foliage of the trees was somewhat sparse, about fifty or sixty percent of that of the check trees.

Maynard in Massachusetts[1] found that although ringing or girdling crab-apple trees increased fruitfulness, he considered that the practice should be applied only under special conditions.

The Geneva New York Station[2] found the practice of ringing to be devitalizing also when applied to other plants such as the tomato, grape, and chrysanthemum.

### Effects of Seasonal Pruning upon Bearing Orchards.

Data as to the effects of seasonal pruning upon bearing orchards were secured from the Boyer orchard. Seventy trees consisting of fourteen rows, five in each row of the Arkansas (Mammoth Black Twig) and York Imperial varieties, fifteen years old at the beginning of the experiment, were used in this test. Five trees of one variety were used in each plot. An outline of the experiment and a general description of the orchard can be found on pages five and seven under the heading "Outline of the West Virginia Experiments." This orchard at the beginning of the experiment was not in a very vigorous condition but under the influence of clean cultivation, leguminous cover crops, and some fertilization it soon became vigorous and healthy.

**Character of Annual Terminal Growth.** The length and diameter of the terminal growth was measured each year in the different plots as it was thought that they would be a good index of the vigor of the trees. The amount of wood removed each year was also weighed and records were kept.

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[1] Mass. Hatch Agr. Exp. Sta., Bull. 1:12-13.

[2] Hedrick, U. P., Taylor, O. M., and Wellington, Richard, N. Y., Agr. Exp. Sta., Bull. 288.

[2] Paddock, Wendell, N. Y. Agr. Exp. Sta., Bull. 151.

TABLE XXXIV.—Character of Annual Terminal Growth and Amount of Wood Removed (Arkansas).

| Method of Pruning | Length in Inches 1911 | Average Length in Inches 1912-'15 | Diameter in Inches 1911 | Average Diameter in Inches 1912-'15 | Weight in lbs. Removed per Tree 1912-'15 |
|---|---|---|---|---|---|
| Heavy dormant | 4.08 | 9.17 | .156 | .189 | 21.79 |
| Moderate dormant | 4.06 | 8.5 | .149 | .181 | 8.33 |
| Light dormant | 4.21 | 7.1 | .158 | .17 | 5.26 |
| Heavy dormant and early summer | 4.22 | 8.52 | .158 | .192 | 30.51 |
| Moderate dormant and early summer | 4.94 | 8.88 | .171 | .187 | 13.87 |
| Early summer | 3.84 | 7.25 | .173 | .169 | 17.66 |
| Midsummer | 4.15 | 8.86 | .171 | .184 | 38.38 |

TABLE XXXV.—Character of Annual Terminal Growth and Amount of Wood Removed (York Imperial).

| Method of Pruning | Length in Inches 1911 | Average Length in Inches 1912-'15 | Diameter in Inches 1911 | Average Diameter in Inches 1912-'15 | Weight in lbs. Removed per Tree 1912-'15 |
|---|---|---|---|---|---|
| Heavy dormant | 4.06 | 5.2 | .153 | .137 | 8.89 |
| Moderate dormant | 3.92 | 4.92 | .152 | .126 | 8.28 |
| Light dormant | 4.69 | 4.09 | .174 | .128 | 5.46 |
| Heavy dormant and early summer | 4.55 | 5.49 | .158 | .14 | 20.38 |
| Moderate dormant and early summer | 5.16 | 5.9 | .16 | .144 | 17.46 |
| Early summer | 4.71 | 4.66 | .165 | .135 | 23.2 |
| Midsummer | 4.85 | 4.37 | .176 | .134 | 12.31 |

It can be seen in Table XXXIV and Table XXXV that in the case of large bearing trees, pruning at different seasons of the year did not influence the terminal growth as did seasonal pruning on very young trees or trees just bearing their first crops. While with the Arkansas variety heavy dormant pruning caused a slightly longer and thicker terminal growth than did the other treatments, it will be noticed that the terminal growths in the other plots are about the same and that none of these are much below those in the heavy dormant pruned plot. In the case of the York Imperial variety the dormant pruned trees and those trees which had a combination of dormant and early summer pruning seemed to have produced slightly more vigorous growth than did either the early summer or midsummer pruned trees, with the exception of the

light dormant pruned trees. These trees produced the weakest terminal growths of all plots. Taken as a whole the summer pruning did not seem to check seriously the terminal growth in middle-aged bearing trees. A study of Tables XXXIV and XXXV shows that as far as effect of summer pruning upon terminal growth is concerned, little can be said. With both varieties, midsummer as well as early summer pruning produced a more vigorous growth than that which followed light dormant, but with one exception less vigorous than that produced by moderate or heavy dormant pruning. It is not thought that the vigorous growth of Arkansas following midsummer pruning has any special significance since this does not hold true with the York Imperial and our experience with younger trees indicates quite clearly that midsummer pruning is more devitalizing than early summer pruning. Taken as a whole the data from this orchard indicate that with middle-aged trees summer pruning may be practiced with less danger of seriously retarding growth than in the case of younger trees. The large amount of wood removed from the summer pruned trees can be explained by the fact that a large proportion of this weight was made up of leaves, which additional weight was not encountered in the case of the dormant pruned trees.

**Fruit Production.** The records which we were able to obtain on fruit production as influenced by seasonal pruning were rather poor, and very little reliance can be placed upon them. In 1912, the year the experiment was started, there was an unusually severe outbreak of cedar rust in the county. This disease checked the development of York Imperial so seriously that no records of the crop were taken that year. It is questionable, however, if the pruning would have had much effect, if any, on the crops the first year. In 1913, a late freeze destroyed all fruit set and yield records were again lost. In 1914, both varieties yielded well and records of the crops were obtained. In 1915, the Arkansas again developed a good crop, but the York Imperial, being a biennial bearer and having borne heavily in 1914, produced practically no crop. Thus, it can be seen that data were obtained on the yield of Arkansas for two years in succession but that the yield for only one year was obtained on the York Imperial variety.

The different seasonal prunings seemed to produce no uniform effects on these bearing trees. In the case of the Arkansas, while midsummer pruning seemed to produce the greatest yields, early summer pruning on the other hand did not materially increase fruitfulness. Likewise the effects of early summer pruning in connection with heavy and moder-

TABLE XXXVI.—Yields of Fruit in the Boyer Orchard per Tree (Arkansas).

Average in Bushels per Tree for 1914 and 1915 Crops.

| Method of Pruning | Bushels $2\frac{1}{4}$" and up | Bushels 0 - $2\frac{1}{4}$" | Total Bushels per Tree | Rank |
|---|---|---|---|---|
| Heavy dormant | 9.53 | .12 | 9.65 | 3 |
| Moderate dormant | 8.05 | .15 | 8.2 | 4 |
| Light dormant | 7.73 | .16 | 7.89 | 5 |
| Heavy dormant and early summer | 10.38 | .16 | 10.54 | 2 |
| Moderate dormant and early summer | 5.56 | .07 | 5.63 | 7 |
| Early summer | 6.51 | .10 | 6.61 | 6 |
| Midsummer | 10.88 | .13 | 11.01 | 1 |

TABLE XXXVII.—Yields of Fruit in the Boyer Orchard per Tree (York Imperial).

Average in Bushels per Tree in 1914 Crop.

| Method of Pruning | Bushels $2\frac{1}{4}$" and up | Bushels 0 - $2\frac{1}{4}$" | Total Bushels per Tree | Rank |
|---|---|---|---|---|
| Heavy dormant | 11.9 | 2.12 | 14.02 | 3 |
| Moderate dormant | 9.95 | 1.99 | 11.94 | 5 |
| Light dormant | 7.9 | 1.25 | 9.15 | 6 |
| Heavy dormant and early summer | 12.5 | 2.5 | 15.00 | 2 |
| Moderate dormant and early summer | 12.75 | 1.06 | 13.81 | 4 |
| Early summer | 14.7 | 1.95 | 16.65 | 1 |
| Midsummer | 7.0 | 1.12 | 8.12 | 7 |

ate dormant pruning were un-uniform and varied. With the York Imperial variety the rank of the different summer prunings was just reversed. In this case, early summer pruning produced the largest yields, while the midsummer pruned trees were the poorest in this respect. Those trees which received both a heavy dormant and an early summer pruning yielded well in both varieties and held the same rank. Likewise the heavy dormant pruned trees yielded well and held the same rank in both varieties.

As stated previously too much weight should not be placed on these results as in the one case they represent only one crop and in the other but two. In the case of the middle-aged trees seasonal pruning did not exert such marked difference as in younger trees. The heavy and moderate dormant prunings seemed to be very satisfactory and uniform in their results, while the results of the different summer prunings were contradictory and unconvincing.

## CONCLUSION.

From the work of the West Virginia Agricultural Experiment Station on the pruning of apple trees several general recommendations may be safely made for conditions of growth as they exist in West Virginia. During the first four or five years after a tree is planted its form must be moulded and consequently pruning must be more or less severe during this period. During the first two or three years as much as three-fourths of the total length of new growth may be removed annually and the vigor of the tree will not only be unimpaired but apparently increased and at the same time a strong compact head is insured. After this, however, continued severe annual pruning and particularly rigorous heading back will surely dwarf the growth and delay fruit bearing. After the second or third year the pruning should be confined almost entirely to branch thinning with heading back practiced only when necessary to maintain the symmetry of the tree. In a two-story tree where the upper scaffold is not started until the third year heading in must be continued on this scaffold for two or three years to make a satisfactory top, but here it should be discontinued as soon as possible. In short, to secure maximum growth together with early fruiting, the pruning during the period from planting to bearing age should be just sufficient to get a well formed head and then to keep the branches properly thinned. In older trees which have been neglected, heavy pruning, both thinning and cutting back to lower the top, may be practiced to stimulate new growth but should be followed in subsequent years only by normal branch thinning. Old trees in good condition should receive light annual thinning of branches.

A great deal has been written and spoken in support of summer pruning but from the experiments already discussed we can only conclude that it is a practice unsuited to West Virginia conditions. In no case did it hasten the fruiting of young trees or increase their crops after they came to a bearing age. On the other hand, it clearly impaired the vigor of the tree. Theoretically, it should check growth and induce fruit bud formation. Unquestionably, it checked growth but the fruit buds failed to follow.

## SUMMARY.

1. This bulletin is a preliminary report of a pruning experiment covering a period of four years and embracing 366 apple trees of various ages. Study has been made of the effects on vigor and fruitfulness of various degrees of dormant pruning, summer pruning at different times, and combinations of dormant and summer pruning.

2. Heavy annual dormant pruning resulted in stronger terminal growth than lighter pruning on trees of all ages.

3. In the study of trees up to five and six years of age it was found that annual heavy dormant pruning was beneficial from the growth standpoint for the first two or three years after which it dwarfed growth so that by the end of the period the lightly pruned trees showed a strikingly greater increase in trunk diameter, branch diameter, size of top, and total annual growth.

4. With trees five or six years old at the close of the experiment heavy annual dormant pruning delayed fruit bud formation and light pruning encouraged it.

5. With trees of bearing age (six or seven years at beginning of test) heavy annual dormant pruning diminished crop production and light annual dormant pruning increased it.

6. With fifteen-year-old bearing trees in only a fair state of vigor heavy annual dormant pruning increased fruit production.

7. Early, midsummer, and repeated summer pruning, as a rule, impaired tree vigor as evidenced by smaller annual growth, smaller leaf area, and light colored foliage. Early summer pruning was less deterrent in its effect than was repeated or midsummer pruning.

8. There is no evidence to show that either early, repeated, or midsummer pruning will hasten the bearing period of young trees or increase crop production of trees of bearing age.

9. Ringing of trees caused heavy crop production the following season but so impaired the vigor that no crop was produced the second or third year, and at least three seasons were required to restore the tree to normal conditions.

10. With normal trees maximum growth and production will be secured by light annual dormant pruning except with trees under three years of age which will respond more satisfactorily to heavy dormant pruning.

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West Virginia University
Agricultural Experiment Station
MORGANTOWN

DEPARTMENT OF SOILS

# METHODS IN SOIL ANALYSIS

## TECHNICAL BULLETIN

BY

Firman E. Bear and Robert M. Salter

Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

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# METHODS IN SOIL ANALYSIS

By FIRMAN E. BEAR and ROBERT M. SALTER.

## INTRODUCTION.

Much importance has been attributed in recent years to the analysis of soils for total constituents. The literature covering the methods for such analysis, while rather extensive, is scattered, and in many cases the methods described are not well suited to rapid routine practice. In view of these facts it has been thought that the compilation and publication of the methods used and in part evolved in the soils laboratory of the West Virginia Agricultural Experiment Station may be of value to others desiring methods which are rapid and at the same time sufficiently accurate to meet the requirements of most soil investigations. The methods are presented in sufficient detail to permit their employment by those who have not had extensive experience in quantitative work.

In the development of these methods access has been had to the methods employed by the New York, Illinois, and Wisconsin experiment stations. Use has also been made of material from procedures as published by the Ohio, Tennessee, and other experiment stations. Much has been adapted from bulletin 422 of the United States Geological Survey.

Most of the methods herein described have been proved reliable by their successful use in several hundred analyses of various types of West Virginia soils.

## CHOOSING SAMPLES.

In sampling any given area three composite samples are ordinarily chosen, representing different depths as follows: sample A, 0 to 6⅔ inches; sample B, 6⅔ to 20 inches; sample C, 20 to 40 inches. A one-inch soil auger is used in securing samples. Sample A is a composite of from 20 to 30 borings, so chosen as to furnish as nearly as possible a truly representative sample of the area in question. Samples B and C are composites of from 10 to 15 borings. As samples are taken in the field they are placed in clean cloth sacks and sent immediately to the laboratory where they are air dried and prepared for analysis.

## PREPARATION OF SAMPLES FOR ANALYSIS.

The samples, after being air dried, are pulverized in a porcelain mortar to pass a 2-mm. sieve, care being taken not to pulverize any pieces of rock or shale. The material which fails to pass the sieve is weighed and its percentage of the whole sample calculated. This material is placed in a glass jar and labeled Discard, No....., A. B. or C.

The material which passes the sieve is thoroughly mixed and a sufficient amount selected by the method of quartering to fill an eight-ounce jar. This latter material is then further pulverized in an agate mortar so that all passes a 100-mesh sieve, no portion being rejected. All samples are stored in tight glass jars of eight- and sixteen-ounce sizes, with metal screw tops.

## MOISTURE.

Five grams of 100-mesh soil are weighed into an aluminum dish provided with tight cover or into a low form weighing bottle with ground glass stopper. The soil is dried for five hours in an oven kept at 110° C. The dish or weighing bottle is cooled in desiccator, covered, and weighed.

## DETERMINATION OF IRON, ALUMINIUM, TITANIUM, MANGANESE, CALCIUM, AND MAGNESIUM.

The procedure outlined for these determinations has been developed with the idea of eliminating the difficulties which arise when silica is determined in the same sample as the above-named elements. This has proved particularly advantageous at the West Virginia Experiment Station laboratory, since in many samples which have been analyzed for these elements the content of silica was not desired. The method depends on the decomposition of the sample by means of hydrofluoric acid.

### Decomposition of Sample.

A one-gram sample of 100-mesh soil is treated in a platinum crucible of 35 cc. capacity with 5 cc. of hydrofluoric acid (48%) and ½ cc. of concentrated sulphuric acid. The mixture is slowly evaporated on a water or sand bath and the excess sulphuric acid driven off by inclining the crucible upon a triangle and cautiously heating the upper portion with a

low flame. When dry the crucible is ignited[1] until organic matter is burned off. From three to five cc. of hydrofluoric acid are added and again slowly evaporated on a water or sand bath. This is repeated until no gritty particles are noticed when residue is rubbed with a platinum spatula, two or three evaporations ordinarily being sufficient. Any fluorides are now changed to sulphates by treating with a few drops of $H_2SO_4$ and volatilizing over a free flame as previously described. The residue is treated with 5 cc. of concentrated HCl and transferred with water to a 500 cc. beaker. The volume at this point should be about 75 cc. The solution is boiled until residue dissolves.[2]

The acid present is partially neutralized with about 6 cc. of 1:1 $NH_4OH$ (14% $NH_3$) and then 10% $Na_2CO_3$ solution is added drop by drop with stirring until the color of the solution tends to darken. The dropwise addition is continued from this point more slowly and with more thorough stirring between drops until the cloudiness produced by one drop seems to increase when stirred rather than to decrease. One or two drops of cencentrated HCl are now added to clear the solution.[3] Ten cc. of 30% sodium acetate solution are added and the volume made up to from 300 to 350 cc. with boiling water. The solution is brought to boiling and boiled from 2 to 3 minutes. After allowing the precipitate to settle it is filtered onto an 11-cm. ashless paper, and sucked dry[4]. It is not necessary to wash the precipitate at this point since it is transferred together with filter back to the original beaker and re-precipitated as follows: Five cc. of concentrated $HNO_3$ are added and the paper is broken up with a sharp glass rod. Water is added to make the volume up to 300 cc. The solution is brought to boiling and $NH_4OH$ is added slowly until a slight excess is indicated by the odor of free $NH_3$. The solution is boiled one minute and allowed to stand until the

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[1] Ignition burns off organic matter and also seems to help in the further decomposition of the silicates by hydrofluoric acid.

[2] A slight amount of insoluble residue is generally present. This probably consists, as found by Robinson (bulletin 122, United States Bureau of Soils), of barium sulphate, zircons and possibly other rare earths, and in some instances small amounts of undecomposed quartz. The amount of $CaSO_4$ derived from ordinary soils is such as to go entirely into solution when boiled with HCl. Any insoluble residue need not be filtered off since it does not interfere with the determination of total oxides, being weighed with oxides and again after pyro-sulphate fusion and reduction by $H_2S$ with the crucible alone.

[3] If more than one or two drops of acid is required to clear the solution, it is better to add an excess of acid and repeat the neutralization with sodium carbonate.

[4] The basic acetate method is used for the first precipitation of total oxides, since there seems to be less tendency for manganese to be co-precipitated with this procedure than where the first precipitation is made with $NH_4OH$. It is open to possible objection that more aluminium passes into the filtrate than with the latter method. However, the subsequent procedure permits of the proper correction for aluminium.

precipitate settles. It is filtered onto an 11-cm. ashless paper and washed several times with hot 2% $NH_4NO_3$ solution (slightly alkaline with $NH_4OH$) with intermediate suction. The first and second filtrates are combined, made acid with $HNO_3$, and evaporated to dryness in a Non-sol or Jena beaker on the water bath. The ammonium salts are now volatilized by heating in an oven kept at 175° C., the beaker being kept covered with a watch glass[1]. The precipitate and paper are placed in a platinum crucible and the paper burned off at low heat. The precipitate is finally heated to constant weight over a Scimatco burner.

### Determination of Iron, and Total Oxides.

The ignited oxides are brought into solution by fusing with 5 g. of potassium pyro-sulphate[2] and dissolving in hot water to which is added 1 cc. of concentrated $H_2SO_4$. The solution is transferred to a 250-cc. Erlenmeyer flask. The volume should be from 75 to 100 cc. The iron is reduced and dissolved platinum precipitated by passing in a slow stream of $H_2S$[3] and gradually raising the solution to boiling[4]. The passage of $H_2S$ and boiling are continued until the precipitated sulphur flocculates when the flask is removed from the flame and allowed to cool somewhat, the gas flow being continued. The solution is filtered into a second Erlenmeyer flask and the precipitate washed with hot water. Precipitate and paper are transferred to the platinum crucible in which the fusion was made. This is then ignited and weighed[5]. Total oxides are secured by subtracting the weight obtained from that previously obtained for crucible plus total oxides. A cor-

[1] The removal of ammonium salts is necessary to facilitate complete recovery of aluminium by subsequent precipitation with manganese.

[2] During fusion with pyro-sulphate care is necessary to prevent loss by spattering. A convenient method is to place crucible (with lid) into a nichrome triangle held in a wooden handle. By holding this in one hand and rotating over flame the fusion may be controlled so as to prevent spattering. By means of a pair of tongs held in the other hand the lid may be removed frequently to note progress of fusion. Fusion at red heat for a few minutes is generally sufficient to produce a clear melt which indicates complete solution of oxides. By rotating the crucible so that the liquid melt congeals on the sides of the crucible, and then plunging it while still hot into cold water, the material is so loosened as to permit rapid solution in hot water.

[3] Passage of $H_2S$ into solution is accomplished by fitting Erlenmeyer flask with 2-hole rubber stopper, one hole carrying a glass tube, the lower end of which is drawn to a fine point and extends to the bottom of the flask. This serves as the inlet tube and is connected to Kipp generator. The other hole of stopper carries a short L-tube, one arm of which extends just below the stopper. This facilitates testing for complete removal of $H_2S$ with lead acetate paper after reduction.

[4] When work can be so arranged, saturation of solution in the cold with $H_2S$, stoppering the flask, and allowing it to stand over night results in complete reduction and in the formation of a precipitate which is easily filtered.

[5] The ignited residue consists of platinum dissolved during pyro-sulphate fusion, together with materials which escaped decomposition by hydrofluoric and sulphuric acids.

rection is obtained later for the amount of aluminium in the original filtrates. $H_2S$ is again conducted through the hot filtrate obtained as previously indicated to reduce any iron which may have been oxidized by contact with air during filtration[1]. The flask is then disconnected and $CO_2$[2] passed through the boiling solution until the $H_2S$ is entirely expelled. This point can be determined by testing with lead acetate paper[3]. The flask is cooled by placing in cold water, continuing the passage of $CO_2$. When cool the iron is immediately titrated with N/25 $KMnO_4$ solution and calculated as grams of $Fe_2O_3$.

## Determination of Titanium.

The solution in which iron was determined is transferred to a 250-cc. graduated flask, 10 cc. of concentrated $H_2SO_4$ are added and the solution is cooled to room temperature. Five cc. of 3% $H_2O_2$[4] (free from fluorides) are added, the solution is brought to mark with water and thoroughly mixed. The amount of titanium is determined by comparing the color produced with that of a standard $Ti_2(SO_4)_3$ solution similarly peroxidized, using a Dubosc colorimeter[5]. The titanium is calculated as grams of $TiO_2$.

## Determination of Manganese.

The residue obtained by the evaporation of the filtrates from the total oxides is dissolved in about 75 cc. of water. Twenty cc. of a saturated solution of bromine and sufficient $NH_4OH$ to dispel the bromine color are added and the solution is brought to boiling. In order to insure complete precipitation the solution is cooled, more bromine water and $NH_4OH$ are added, and it is again brought to boiling. If necessary this operation is repeated. The flocculant precipitate is filtered upon an ashless paper and washed with hot

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[1] A slight opalescence due to sulphur may appear at this point but does not interfere with the subsequent permanganate titration.

[2] Generated in Kipp from marble. Gas is passed through wash bottle containing acid $CuSO_4$ solution to free from $H_2S$.

[3] Prepared by soaking filter paper in 3% lead acetate solution and drying.

[4] Hydrogen peroxide should be free from fluorides which bleach the color produced. Sulphuric acid tends to counteract the bleaching effect of alkali sulphates present (see Merwin, Am. Jour. Sci., Vol. 28, p. 119).

[5] The standard titanium solution is conveniently made up by dissolving sufficient $Ti_2(SO_4)_3$ in dilute $H_2SO_4$ so that the resulting solution contains titanium equivalent to 0.0100 grams $TiO_2$ per 10 cc. The exact strength of this solution is determined by precipitation of known volume with $NH_4OH$, igniting and weighing up the $TiO_2$ formed. The color standard is made up by oxidizing 10 cc. of above-mentioned solution with $H_2O_2$ and diluting to 250 cc.

water[1]. Paper and precipitate are transferred to a previously weighed platinum crucible, ignited, and weighed. The weight of precipitate represents $Mn_3O_4$ plus the $Al_2O_3$ recovered from the original filtrates. The precipitate is brought into solution by fusion with about 1 gram of potassium pyrosulphate and dissolving in from 50 to 75 cc. of hot water. The solution is transferred to a 250-cc. graduated flask and made strongly acid with $H_2SO_4$. Ten cc. of .2% $AgNO_3$ solution are added for each milligram of metallic Mn, and this followed by about 1 gram solid ammonium persulphate. The flask is placed on a steam bath until a pink color appears when it is removed and placed in cold water. When color is fully developed the flask is filled to the mark and contents are thoroughly mixed. The amount of manganese is determined by comparison in Dubosc colorimeter of the color obtained with that of a standard[2] prepared by acidifying a standard $KMnO_4$ solution, reducing with sulphurous acid, re-oxidizing as with the regular sample, and diluting appropriately. The amount of Mn determined is calculated as $Mn_3O_4$ and this subtracted from the weight of $Mn_3O_4 + Al_2O_3$ previously obtained. The difference represents the $Al_2O_3$ recovered from the filtrate from the total oxide precipitation and is added to the total oxides previously determined.

### Determination of Aluminium.

Aluminium is determined as $Al_2O_3$ by subtracting the sum of the weights of $Fe_2O_3$, $TiO_2$, and $P_2O_5$ from the corrected weight of total oxides ($P_2O_5$ determined in separate sample).

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[1] A different procedure, permitting the determination of manganese gravimetrically, may be used instead of the colorimetric method outlined. However, it is more difficult to get accurate results gravimetrically due to difficulty in completely separating the Al and Mn. The procedure from this point is as follows: Paper and precipitate are transferred to a small beaker, paper is broken up with glass rod, and precipitate is dissolved in sulphurous acid. The solution is heated to boiling and enough $NH_4OH$ added to make just alkaline to litmus. It is filtered immediately and the precipitate washed several times with hot 2% $NH_4NO_3$ solution. Precipitate and paper are transferred to weighed platinum crucible and ignited. Weight of residue found is added to that of total oxides previously determined. The manganese is determined in the filtrate by precipitation with $NH_4OH$ and bromine as before. (The addition of sufficient strong KOH solution to keep any traces of $Al(OH)_3$ in solution tends to give better results). The flocculent precipitate, which should be almost black, is filtered on ashless paper, washed thoroughly with hot water, transferred with paper to weighed platinum crucible and ignited to constant weight. The residue consists of $Mn_3O_4$ and is calculated to MnO. Factor = 0.93006 Log = $\bar{1}$.06851.

[2] The standard is conveniently made to contain .0025 g. MnO per 250 cc.

## Determination of Calcium.

The filtrate from the manganese precipitation is regulated to a volume of 150 cc. and heated to boiling. Ten cc. of saturated ammonium oxalate are added slowly, the solution being kept boiling meanwhile. The solution is further boiled for 15 minutes and filtered through a close-textured filter (C. S. & S. Blue Ribbon), the precipitate being washed free from oxalates with hot water. The precipitate is dissolved into an Erlenmeyer flask by passing warm dilute $H_2SO_4$ (1 : 10 at about 70° C.) through the filter. The oxalic acid formed is titrated warm with N/25 $KMnO_4$ and the calcium calculated as CaO. One cc. N/25 $KMnO_4 = 0.00112$ g. CaO. The precipitation of calcium is never complete, as a certain amount of calcium oxalate is always required to saturate the solution in which the precipitation is made. This amount is practically constant and equal under the aforementioned conditions to 0.0007 g. CaO.

## Determination of Magnesium.

To the cold filtrate from the Ca precipitation are added 5 cc. of 10% solution of microcosmic salt ($NaNH_4HPO_4$) and 10 cc. of $NH_4OH$ (1 : 1). Precipitation is started by stirring and rubbing the walls of beaker with a glass rod. After being allowed to stand over night the precipitate is brought upon a close-textured filter paper, washed with cold 2% $NH_4OH$, and dissolved back into the original beaker with warm, dilute HCl (1 : 10) and hot water[1]. The magnesium is re-precipitated in a volume of about 75 cc. as follows: The solution is made neutral or just alkaline to litmus with $NH_4OH$ and 1 cc. of 10% $NaNH_4HPO_4$ solution is added. After standing 15 minutes, 10 cc. of concentrated $NH_4OH$ (28% $NH_3$) are added and the solution is allowed to stand two hours. The precipitate is filtered upon a close-textured ashless paper and washed with 2% $NH_4OH$ solution. Filter and precipitate are transferred to weighed platinum crucible, ignited, and weighed. The calcium which failed to precipitate as oxalate appears in the ignited residue as $Ca_3(PO_4)_2$ and necessitates a correction of .0013 g. equivalent to the .0007 g.

[1] A re-precipitation is necessary since if the first precipitate is ignited directly the residue may not contain all the magnesium as pyro-phosphate (See Hillebrand, bulletin 422, United States Geological Survey, p. 123).

CaO added to the calcium obtained by titration[1]. The magnesium exists in the residue as $Mg_2P_2O_7$ and is calculated as MgO. Factor = 0.36207, Log. = $\bar{1}$.55879.

### Blank Determination.

A blank is run using the same amounts of reagents and the appropriate corrections are applied[2].

## DETERMINATION OF POTASSIUM.

The fusion for potassium is made according to the method of Laurence Smith for total alkalies. Potassium is precipitated as chloroplatinate without previous removal of calcium which is subsequently removed by means of acidulated alcohol wash. (See Moore, J. Am. Chem. Soc., Vol. XX, pp. 340-343.) Potassium is weighed as chloroplatinate.

### Solutions.

**Platinic Chloride Solution.**—Eighteen grams of the salt are dissolved in water, made slightly acid with HCl, and diluted to one liter.

**Acidulated Alcohol Wash.**—To 3000 cc. of 95% alcohol are added 230 cc. of HCl, sp. gr. 1.20. HCl gas is conducted into the mixture until it shows a normality of approximately 2.25 by titration. The mixture must be kept cool during this process. The HCl gas is generated by treating c. p. NaCl with concentrated sulphuric acid.

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[1] The amount of CaO precipitated with magnesium was found to be quite uniform in amount and equal under outlined conditions to .0007 g. CaO. This correction is the same as that found necessary by Robinson (bulletin 122, United States Bureau of Soils). The calcium occurs in the magnesium residue as $Ca_3(PO_4)_2$ (See Hillebrand, bulletin 422, United States Geological Survey, p. 127).

The exact amount of this correction for any given set of conditions may be determined by method outlined by Hillebrand as follows:

The magnesium pyro-phosphate is dissolved in a little dilute sulphuric acid, and enough absolute alcohol added to make from 90 to 95% of final volume. After several hours the fine precipitate of calcium sulphate is brought on a close-textured filter and washed free of phosphoric acid with 95% alcohol. It is then dissolved in hot water, acidified with hydrochloric acid, made alkaline with ammonia, heated to boiling and the calcium precipitated by adding a few crystals of ammonium oxalate. In a short time it may be filtered, ignited, and weighed as CaO.

[2] A blank run on the reagents used in this laboratory gave the following values:

| | | |
|---|---|---|
| $Fe_2O_3$ | = | .0007 gram. |
| $Al_2O_3$ | = | .0011 gram. |
| $TiO_2$ | = | none. |
| MnO | = | none. |
| CaO | = | .0004 gram. |
| MgO | = | .0002 gram. |

**80% Alcohol Wash.**—Made by diluting 95% alcohol to a specific gravity of .864 at 15.6° C.

**Gladding Wash.**—Made by dissolving 200 grams of ammonium chloride in water and diluting to 1 liter.

## Procedure.

Five-tenths of a gram of 100-mesh soil is weighed and thoroughly ground with .5 gram of $NH_4Cl$ in agate mortar. Four grams of calcium carbonate are added and the mixture is ground until well mixed. Sufficient calcium carbonate is placed in a 35-cc. platinum crucible to cover the bottom and the mixture added by first brushing onto a sheet of glazed paper and then transferring to crucible. About .5 gram of calcium carbonate is ground in the mortar, brushed onto the paper and transferred to crucible together with brushings from paper on which mortar has stood. After tapping to settle contents, the crucible is covered with lid and placed in a hole in an asbestos board held in an inclined position. The hole in the asbestos board should be of such size as to allow about two-thirds of the depth of the crucible to project below the board. The crucible is first heated with a low flame until the odor of ammonia is no longer noticeable (10 to 15 minutes) when the flame is turned up and the crucible heated at the full heat of a Scimatco burner for 45 minutes. The lid of the crucible should stay well below red heat during fusion. After cooling, the fused mass is loosened with a glass rod and transferred to a porcelain casserole. The lid is washed with hot water and the crucible filled with hot water and allowed to stand for a few minutes. The contents of the crucible are washed into the casserole and the fusion is crushed with an agate pestle. The casserole is covered with a watch glass and digested on the water bath for two hours or allowed to stand over night. After thorough slaking, the mixture is stirred and the liquid decanted into a coarse alundum filtering crucible[1] receiving the filtrate in a 400-cc. beaker. Boiling water is added, the mixture stirred and again decanted into filter. This is repeated two or three times when the whole fusion is transferred to the crucible and washed with hot water until the filtrate measures about 300 cc. Ten cc. of HCl, sp. gr.

[1] Filtering through a coarse alundum filtering crucible was found preferable to filtering through paper since the former eliminates a slimy material which seems to be derived from the action of caustic lime upon the filter paper and which is difficult to wash out in the final filtration.

1.20, are added and the filtrate is evaporated to dryness on the water bath, taken up with hot water and filtered into 150-cc. beaker. The filter is washed until filtrate nearly fills beaker. One cc. of concentrated HCl and 5 cc. of platinic chloride solution are added and the filtrate is evaporated on the water bath until residue just solidifies. The residue is treated with from 15 to 20 cc. of acidulated alcohol and stirred until the calcium chloride all dissolves. The liquid is decanted into previously weighed Gooch crucible, using disc of "S. & S. Blue Ribbon" filter paper instead of asbestos mat as filtering medium[1]. The precipitate is transferred to crucible and thoroughly washed with 80% alcohol. It is then washed 10 or 12 times with small amounts of Gladding wash, followed by 10 or 12 washings with 80% alcohol. The crucible is placed in drying oven at 115° C. for 20 minutes, then cooled and weighed. A blank is run on the reagents used and subtracted from the weight of $K_2PtCl_6$ obtained.

$$\text{Factor } \frac{2K}{K_2PtCl_6} = 0.1608 \quad \text{Log.} = \bar{1}.20643.$$

## DETERMINATION OF PHOSPHORUS.

### Solutions.

**Magnesium Nitrate Solution.**—1000 grams of magnesium nitrate are dissolved in 1000 cc. of water.

**Aqua Regia.**—Three volumes HCl, sp. gr. 1.19, and one volume $HNO_3$, sp. gr. 1.42 are mixed and allowed to stand until fumes cease to be given off.

**Molybdate Solution.**—100 grams of molybdic acid, Baker's c. p. 99% are dissolved in 144 cc. of ammonium hydroxide, specific gravity 0.90, and 271 cc. of water. The solution thus obtained is poured slowly with stirring into 489 cc. of nitric acid, specific gravity 1.42, and 1148 cc. of water. A few drops of dilute sodium phosphate solution are added and the molybdate solution allowed to stand several days in a warm place. The clear solution is then siphoned off and preserved in a glass stoppered bottle.

[1] Discs of "S. & S. Blue Ribbon" filter paper are used in preference to asbestos since they permit more rapid filtration, are less liable to lose in weight, require less washing, and dry more quickly. After drying, the crucible must be handled carefully to prevent loss of precipitate.

**Wash Solutions.**—No. 1 solution containing approximately 1% nitric acid and 3% ammonium nitrate is made by adding sufficient water to 30 grams of ammonium nitrate and 10 cc. of nitric acid, sp. gr. 1.42, to make 1 liter of solution. No. 2 solution containing 3% ammonium nitrate is made by dissolving 30 grams ammonium nitrate in one liter of water.

**Standard $HNO_3$ Solution.**—Solution is made to contain 0.009339 gram $HNO_3$ per cc. equivalent to 0.0002 gram phosphorus as ammonium-phospho-molybdate.

**Standard NaOH Solution** (Free from carbonates).—Solution is mde to contain .005929 gram NaOH per cc., equivalent to 0.0002 gram phosphorus as ammonium-phospho-molybdate. Enough $BaCl_2$ is added to precipitate any carbonates as $BaCO_3$.

**Phenolphthalein Solution.**—A 5% phenolphthalein solution in 95% alcohol.

## Procedure.

Five grams of 100-mesh soil are weighed and transferred to a 100-cc. porcelain dish. To this 5 cc. of $Mg(NO_3)_2$ solution are added, the mixture brought to dryness on a water bath, and dried one hour in electric oven at from 110° to 120° C. It is then ignited until all organic matter is burned off, the ignition being started with a low flame and finished at low red heat. When cool, the mass is moistened with a small amount of water and broken up with a glass rod. The dish is covered with a watch glass and 20 cc. of aqua regia are added through the lip after which the mixture is digested on boiling water bath for two hours with occasional stirring to break up lumps. The material is transferred to a 250-cc. graduated flask by washing through a glass funnel, and, after cooling to room temperature, made up to mark with water. After thorough shaking the solution is either filtered through a dry folded filter into a dry beaker or allowed to stand over night. If filtered, 200 cc. of the clear filtrate, or in the latter case, 200 cc. of clear supernatant liquid are pipetted off and evaporated to dryness on water bath in beaker of 400 cc. capacity. The residue is taken up with 10 cc. of dilute nitric acid (1:4 )and again brought to dryness, after which it is dehydrated for 1 hour in oven at from 110° to 120° C. The residue is taken up with 5 cc. $HNO_3$, sp. gr. 1.42, and hot water, and filtered with suction into 250-cc. Erlenmeyer flask, thoroughly washing filter with hot water. The filtrate is evaporated to a volume of approximately 50 cc. on water

bath[1]. Five grams of ammonium nitrate are added and when in solution 20 cc. of molybdate solution are added. The flask is shaken on a mechanical shaker for 15 minutes and then allowed to stand in oven at from 60° to 65° C. for two hours. The precipitate is filtered upon a 9-cm. filter (S. & S. Blue Ribbon filter or paper of similar quality) and washed three times with wash solution No. 1. The precipitate is dissolved back into original flask with warm ammonium hydroxide solution (1:9) and the filter washed thoroughly with hot water[2]. If filtrate exceeds 50 cc. it is reduced to this volume on the water bath. Three grams of ammonium nitrate are then added, followed by 3 cc. of molybdate solution. (With

[1] The greatest difficulty in the determination of phosphorus lies in the proper adjustment of concentrations in the precipitating solution so as to bring about complete precipitation of all phosphorus and yet produce a precipitate free from molybdic acid, and of good physical condition. Complete precipitation is favored by high temperature, large excess of molybdate solution, presence of $NH_4NO_3$, and long standing. (Hibbard, J. Ind. & Eng. Chem. Vol. 5, pp. 998-1010.) However, these factors also all tend to cause the precipitation of molybdic acid. To counteract this tendency for $MoO_3$ to separate, a certain amount of $HNO_3$ is used, this acting through its solvent effect on $MoO_3$. Too great an excess of $HNO_3$, however, causes solubility of ammonium-phospho-molybdate and low results.

In working with soils there are present in some cases large amounts of iron salts which, as shown by Hibbard, tend to cause incomplete precipitations, but this may be remedied by a large excess of molybdate solution. Robinson (See J. Ind. & Eng. Chem. Vol. 8, pp. 148-151) states that soils contain appreciable amounts of vanadium (0.01 to 0.08%) which cause low results when precipitation is carried out under the conditions necessary for the determination of phosphorus by direct titration of the yellow precipitate. This he shows to be due to incomplete precipitation of phosphorus and remedies by reduction of vanadium with ferrous sulphate and precipitation of phosphorus in the cold with mechanical agitation. However, he writes. "By taking precautions to make the precipitation of phospho-molybdate complete by means of comparatively large excess of reagents, and by digestion and mechanical agitation, the influence of the amount of vanadium ordinarily found in soil can be avoided without reducing the vanadium, provided the yellow precipitate is converted to magnesium ammonium phosphate." The error due to presence of vanadium is probably much decreased if not entirely eliminated by a second precipitation if the conditions of the first precipitation are such as to induce complete precipitation of phosphorus.

On account of the difficulty in overcoming the above-mentioned errors, and at the same time obtaining a precipitate free from $MoO_3$ and containing all the phosphorus as ammonium-phospho-molybdate it was thought advisable to make two precipitations, the first being made under conditions inducing complete precipitation but not tending toward absolute purity of precipitate, while the second precipitation, made in the absence of all but traces of impurities, would be more easily adjusted to obtain complete precipitation with freedom from $MoO_3$.

Conditions of first precipitation:

Volume — 70 cc.
Phosphorus — .0008 to .0080 gram.
$(NH_4)_2MoO_4$ — approximately 2%.
$HNO_3$ — approximately 8%.
Mechanical shaking, 15 minutes in cold.
Digestion at 60° to 65° C. for two hours.

Conditions of second precipitation:

Volume — 50 cc.
Phosphorus — .0008 to .0080 gram.
$(NH_4)_2MoO_4$ — 0.4 to 1% (About double theoretical amount).
$HNO_3$ — 2%.
$NH_4NO_3$ — 6%.
Precipitation at exactly 60° C. with mechanical shaking for 3 minutes.

EQUATION:

$$NH_4H_2PO_4 + 12NH_4MoO_4 + 22HNO_3 = (NH_4)_3PO_4(MoO_3)_{12} + 22NH_4NO_3 + 12H_2O$$

[2] The appearance of a feathery white precipitate at this point indicates incomplete removal of bases, iron, aluminium, and more particularly titanium, which separate, probably as phosphates, in the alkaline solution. Robinson (previous reference) found that a second precipitation reduced the amount of feathery precipitate to a practically negligible quantity.

soils high in phosphorus, as indicated by a large amount of yellow precipitate in first precipitation, from 5 to 7 cc. of molybdate solution should be used). If a precipitate appears at this point it is re-dissolved by the addition of a little ammonium hydroxide. The solution is then brought to 60° C. (conveniently kept in oven at that temperature) and concentrated nitric acid added from burette, a drop at a time, until the color of solution turns permanently yellow, after which just one cc. more is added and the flask shaken for three minutes. The solution is filtered immediately and the precipitate washed three times with wash solution No. 1, three times with wash solution No. 2, and finally three times with water. The precipitate and filter are returned to flask in which precipitation was made and 25 cc. of standard NaOH solution are added from an automatic overflow pipette, rotating the flask so as to dissolve any precipitate adhering to the inner surface. (If soil contains more than 0.100% phosphorus, 50 cc. of NaOH should be added.) The sides of flask are washed down with distilled water and the filter is broken up with a glass rod. When yellow precipitate is all dissolved, 40 cc. of $CO_2$-free distilled water are added and the solution is titrated with standard $HNO_3$ solution using phenolphthalein indicator. When approaching the end point in the titration the flask is stoppered with rubber stopper and shaken to break up the filter thoroughly after which the titration is completed[1].

$$\text{Percent } P = \frac{\text{cc. of NaOH} - \text{cc. of } HNO_3{}^{2}}{200}$$

## DETERMINATION OF TOTAL NITROGEN.

### Solutions.

**Alkali Solution.**—Ten pounds Greenbank's alkali and 125 grams $K_2S$ are dissolved in 5 liters of water.

**Standard Acid.**—5/14 normal $H_2SO_4$ is used. Arranged to deliver 10 cc. from automatic overflow pipette.

**Standard Alkali.**—N/14 NaOH is used, 1 cc. equivalent to 1 mg. N.

### Procedure.

Ten grams of 100-mesh soil[3] are digested in 800 cc. Kjeldahl flask with 20 cc.[4] concentrated $H_2SO_4$ and 0.4 g.

[1] A blank determination should be run, using the same quantity of reagents as in regular determination.

[2] Equation used in calculation:
$(NH_4)_3PO_4(MoO_3)_{12} + 23NaOH = (NH_4)_2HPO_4 + 11H_2O + NH_4NaMoO_4$

[3] The use of soil ground to 100 mesh largely eliminates bumping during digestion.

[4] Soils high in clay or organic matter may require 25 cc. $H_2SO_4$ with subsequent use of 60 cc. of strong alkali.

metallic mercury (6 drops from burette) at low heat for 20 minutes. Five to ten grams $K_2SO_4$ are added and the digestion continued at full heat for 1½ hours or until residue is white. When cool 300 cc. of water and a few pieces of mossy zinc are added, 50 cc. of alkali solution poured down neck of flask, and the ammonia distilled into 10 cc. of 5/14 normal $H_2SO_4$. The distillate, which should measure about 200 cc., is titrated with N/14 NaOH, using alizarin red indicator. A blank is run on the reagents. Duplicates should check within 0.1 cc. equivalent to 0.001%.

$$\text{Percent N} = \frac{\text{Titration of blank} - \text{Titration of sample.}}{100}$$

## DETERMINATION OF TOTAL CARBON.

The method used[1] is an adaptation with modifications of the method described by Fleming[2] for the rapid determination of carbon in iron and steel. It depends upon the direct combustion of the soil in a current of oxygen, the gases being dried by phosphoric anhydride and the carbon dioxide absorbed in soda-lime and determined by weight.

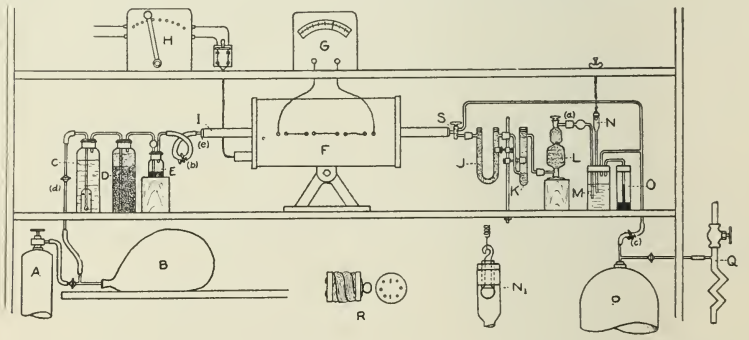


FIG. 1.

A—High Pressure Oxygen Tank, 150 gal., 1800 lbs. pressure. (S. S. White Dental Co., c. p. oxygen).
B—Rubber Bag, 1 gal. capacity. C—30 percent KOH Solution.
D—Granular, Anhydrous $CaCl_2$ (below), Separated by Layer of Asbestos Fiber from 20-mesh Soda-Lime (above).
E—Mercury Valve Bottle. F—Electric Combustion Furnace. H—Rheostat.
I—Silica Combustion Tube, Glazed, 24 in. long by ⅞ in. inside diameter.
J—U-tube Containing 2-mm. Granulated Zinc.
K—$P_2O_5$ Supported on Glass Wool. L—Fleming Soda-Lime Absorption Bulb.
M—Suction Bottle. N—Safety Valve, Ground Glass (shown below at $N_1$).
O—Mercury Suction Gauge. P—10 gal. Suction Tank.
Q—Water Suction Pump. R—Asbestos Plug. S—Two-way Stopcock.

[1] Published in Jour. Ind. & Eng. Chem., July, 1916, Vol. 8, pp. 637-639.
[2] The Iron Age, Vol. 93, pp. 64-66.

In the apparatus shown in Fig. 1, the gas enters bottle C, through a Folin absorption tube. The KOH solution frees the oxygen from any traces of carbon dioxide. D dries the gas and insures freedom from carbon dioxide. The mercury valve bottle prevents gas from backing into bottles C and D. The furnace F is an Eimer and Amend, having replaceable heating units, but is modified by installing 4 platinum-nichrome thermocouples connected in series to galvanometer G, so as to show the furnace temperature at all times; the scale on the galvonometer is calibrated by comparison with a standard pyrometer. The tube I contains, just within the exit end of the furnace, 5 in. of coarsely granular cupric oxide, held in position by 2 plugs of asbestos fiber. J, containing granular zinc, serves to stop sulphur, chlorine or acid fumes; it also acts as a filter. K removes moisture from the gases, and as the $P_2O_5$ liquefies it is absorbed by the glass wool, more anhydride being added from above. The lower portion of the absorption bulb L is filled with alternate layers of Baker's 20- and 40-mesh soda-lime, the quantity used being sufficient for 60 or more determinations of total carbon in average soils. The upper portion contains $P_2O_5$, which insures the gases leaving the bulb with the same moisture content as on entering. The valve N prevents accidental drawing of mercury from O into M and facilitates regulation of suction. The suction tank P gives more uniform suction than the pump alone, and one exhaustion serves for 15 or more determinations. R is made by joining two perforated discs of asbestos board by means of a stiff nichrome wire (B. & S. gauge 20) so as to leave a loop at one end by which the plug may be withdrawn from the combustion tube. Between the two asbestos discs is some loose asbestos fiber, held in place by a spiral of nichrome wire. The stop-cock S permits the drawing of oxygen through the combustion tube without allowing it to pass through the absorption end of the train. The whole apparatus is permanently set up in an electrically lighted case with sliding glass doors.

## Procedure.

A two-gram sample of soil[1] is weighed, mixed with 2 to 3 g. of 40-mesh alundum and transferred to an alundum boat[2]. Before introducing the sample into the combustion

[1] With soils containing over 5 percent total carbon, a one-gram sample is sufficient.

[2] Convenient size of the boat for two-gram sample is 3¾ in. by ⅝ in., outside dimensions. Alundum mixed with soil increases porosity and insures access of oxygen to all parts. "R. R. Alundum, alkali-free, especially prepared for carbon determinations," is used.

tube[1] it is necessary to see that the exit tube of the absorption bulb is disconnected from the suction bottle at the point (a), that the two-way stopcock S stands in a position to permit gas entering the absorption end of the train, and that the screw clamps (b) and (c) and stopcock (d) are closed. The furnace[2] should stand at a temperature of from 925° to 950° C. The boat is introduced into the end of the combustion tube, followed by asbestos plug R. Both are then pushed to the center of the furnace by means of a stiff nichrome wire and connection (e) is quickly made. After a few seconds to allow the gas immediately produced to escape, screw clamp (b) is opened and connection (a) closed. Sufficient suction, measured by mercury gauge O, to produce somewhat more than desired rate of gas flow (previously determined) is then applied. The gas flow is regulated by adjusting stopcock (d) so that 750 cc. to 1000 cc. of oxygen pass through the apparatus in 20 minutes, which is sufficient time to complete combustion[3]. The temperature is maintained at from 925° to 950° C. throughout the combustion. The absorption tube[4] is finally disconnected, both inlet and exit closed, allowed to stand on the balance pan 15 minutes and weighed[5].

Duplicate determinations should check within .01% total carbon, equivalent to about 0.0007 g. $CO_2$ on a two-gram sample.

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[1] Before starting a single determination, or a series of determinations, the apparatus should be connected up and sufficient oxygen passed through to burn out any carbon contained in the asbestos plugs and to sweep out the air originally in the train. The further passage of oxygen should produce no increase in the weight of absorption bulb.

[2] Care must be observed to prevent the furnace attaining a temperature of much over 1000° C., as cupric oxide fuses at 1064° C. and when this occurs the silica tube slags with the fused oxide and invariably cracks on cooling. A temperature of over 825° C. is necessary to insure decomposition of carbonates.

[3] Drawing the gas through by suction is found preferable to forcing it through by pressure, it being much easier to prevent leakage. Any error from this source would be comparatively insignificant as the leakage would be inward rather than outward. The content of $CO_2$ in ordinary air is such that it would require an inward leakage of approximately 160 cc. to cause an increase of 0.0001 g. in the weight of the absorption bulb. All connections, where possible, were made of rubber stoppers, these being less liable to develop leaks than connections of rubber tubing.

[4] The Fleming absorption bulb was found to be very efficient, it being possible to increase the rate of gas flow 5 to 8 times that actually used without danger of incomplete absorption of $CO_2$.

[5] Due to the rather large size of the absorption bulb, some precaution is necessary in weighing to prevent errors due to differences in the amounts of moisture condensed on the surface of the bulb and to changes in temperature and atmospheric pressure. By using a second bulb or glass bottle of approximately the same weight, containing about the same quantity of soda-lime, as a tare in weighing, these errors are rendered insignificant.

## DETERMINATION OF TOTAL SULPHUR.

### Procedure.

Two grams of 100-mesh soil are mixed in a platinum crucible with 7 grams of anhydrous $Na_2CO_3$ of low sulphur content and .5 gram $KNO_3$. The crucible is covered with lid and placed in a hole in an asbestos board supported in a horizontal position. The hole in the asbestos board should be just large enough to permit about three-fourths of the crucible to extend below the board. The board itself should be large enough to prevent, as far as possible, the gases of the flame from coming in contact with the top of the crucible. The mixture is heated to quiet fusion with the full heat of a Scimatco burner. The crucible is now grasped in the tongs and rotated in such a way as to cause the melt to solidify upon the sides of the crucible, and while still hot, plunged into cold water to loosen the melt. Crucible and lid are placed in a 400-cc. beaker, covered with boiling water, and allowed to stand with occasional stirring until melt dissolves. The solution is then filtered onto an 11-cm. filter into a 400-cc. beaker and the residue washed with water until the filtrate measures 250 to 300 cc. A drop of alcohol is added to the cold filtrate to reduce any maganese, and then HCl from a burette with stirring until the solution is acid to litmus, avoiding an excess. The solution is heated to boiling and 5 cc. of 10% $BaCl_2$ solution added with stirring. Boiling is continued for 5 minutes and the solution allowed to stand over night. The precipitated $BaSO_4$ is filtered onto a close-textured ashless paper (S. & S. Blue Ribbon) and washed with hot water until free from chlorides. Paper and precipitate are transferred to weighed platinum crucible and ignited and sulphur weighed as $BaSO_4$. If care is taken to have the solution cold and the volume about 300 cc. when neutralized with HCl, there is no danger of contamination of precipitate with silica. If such contamination occurs, the residue after ignition must be treated with a few drops of hydrofluoric acid and one drop of sulphuric acid. This is evaporated to dryness and the crucible re-ignited. A blank determination is run on the regeants employed.

$$\text{Factor } \frac{S}{BaSO_4} = 0.1374 \quad \text{Log. } \bar{1}.13793$$

## DETERMINATION OF SILICA.

### Procedure[1].

One gram of 100-mesh soil is mixed with 5 grams of sodium peroxide in an iron or nickel crucible. If the soil is low in organic matter .05 gram of starch is mixed with the soil before the peroxide is added. The mixture is heated carefully, the flame of the Bunsen being directed upon the charge and upon the side of the crucible until the action starts. The crucible is covered until the reaction is over and then kept at a dull red heat for 15 minutes. The contents of the crucible are transferred to a casserole and the crucible is washed out with a little hot water. The casserole is covered with a watch glass, and 75 cc. HCl (HCl, sp. gr. 1.2 diluted with 2 parts of water) are added through the lip. The mixture is evaporated on the water bath with occasional stirring until crumbling starts when 15 cc. HCl (1 part HCl, sp. gr. 1.2, to 1 part water) are added, the casserole is covered with a watch glass and digested on water bath for 10 to 15 minutes. Ten cc. of water are added and the silica is filtered with suction upon an 11-cm. ashless paper and washed with a hot solution of 5 cc. HCl, sp. gr. 1.2, to 95 cc. of water. The filtrate is evaporated to dryness and the residue dehydrated in the oven at 110° C. for 2 hours. The residue is taken up with 10 cc. of HCl (1 part HCl, sp. gr. 1.2, to 1 part water), covered and digested on water bath from 10 to 15 minutes. Forty cc. of water are added and the silica is filtered immediately onto 9-cm. ashless paper and washed with cold dilute HCl (1 cc. concentrated HCl to 99 cc. water). Paper and silica from second dehydration are placed in 35-cc. platinum crucible and the paper is carefully burned off. Paper and silica from the first dehydration are added and the silica is ignited to constant weight over Scimatco burner. Ten cc. of hydrofluoric acid and a few drops of sulphuric acid are added to crucible and the silica is volatilized by evaporation to dryness. The residue is ignited and weighed. Loss in weight represents $SiO_2$.

[1] Adapted from method of Lehner and Truog, J. Am. Chem. Soc., Vol. 38, pp. 1050-1063.

## DETERMINATION OF CARBONATE CARBON.

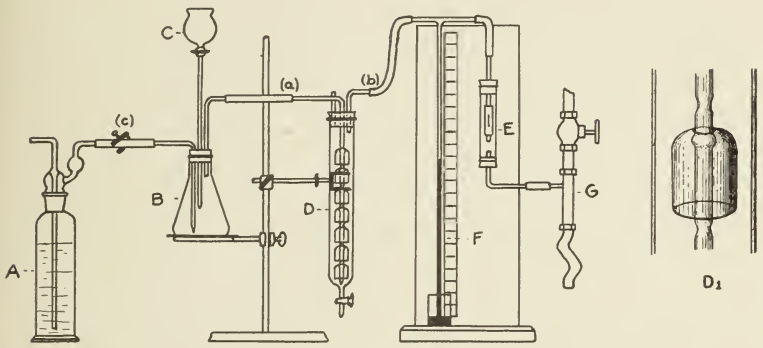


FIG. 2.

A—Gas Washing Bottle (Containing 30% KOH solution).
B—Wide Mouth Erlenmeyer Flask (200 cc. capacity). C—Extraction Funnel.
D—Absorption Tube, (Shown in detail at $D_1$). E—Bunsen Valve.
F—Mercury Suction Gauge. G—Suction Pump.

The method consists in the decomposition of the carbonates present in the sample by means of 1:10 HCl *in vacuo*. The $CO_2$ is expelled by means of a current of air and absorbed in standard NaOH solution. Barium chloride is added and the excess alkali titrated with standard HCl.

The absorption tube, which was designed and made in this laboratory, is very efficient and has an advantage over a tube containing glass beads in that it is more easily washed free from alkali.

### Procedure.

Ten grams[1] of 100-mesh soil are placed in flask B and this connected up as shown in Fig. 2. Screw clamp (c) is closed. Absorption tube D is charged with 25 cc. of N/4 NaOH, measured by means of automatic overflow pipette, together with sufficient $CO_2$-free distilled water to cover the floats and a few drops of phenolphthalein indicator. Forty cc. of 1:10 HCl are run in from funnel C and the suction turned on very gradually until it equals 18 inches of mercury. Screw clamp (c) is then opened sufficiently to allow a slow current of air to pass through the apparatus (30 to 40 bubbles per minute in bottle A). The air current is continued with frequent agitation of flask for 30 minutes, when the suction is shut off and the absorption tube disconnected at points (a) and (b) and removed from the clamp. The contents of the

[1] On soils containing over 0.25% carbonate carbon a 5-gram sample is used.

absorption tube are run into a 300-cc. Erlenmeyer flask and the tube is washed three times with 40-cc. portions of $CO_2$-free water, run into tube through hole in stopper. During washing the tube is revolved sufficiently to wash the inner surfaces of the absorbing floats. Five cc. of neutral 10% $BaCl_2 \cdot 2H_2O$ solution are added and the solution titrated with N/10 HCl, using phenolphthalein indicator. A blank is run using the same amounts of reagents and water.

Percent of Carbonate Carbon = .012 (Titration of Blank — Titration of Sample.)

Duplicate should check within 0.1 cc. equivalent to .0012% on a 10-gram sample.

## DETERMINATION OF LIME REQUIREMENT.

The method in use in this laboratory for the determination of the lime requirement is a combination of the method of Veitch[1] with that of Truog[2]. The principal objection to the Veitch determination as ordinarly carried out is the number of determinations that must be run before the correct end point is obtained. It has been found possible to eliminate one-half or more of these determinations by first running a Truog test on the sample and comparing the test paper obtained with a chart composed of test papers from a series of soils of varying lime requirements previously determined by the Veitch method.

### Reagents.

**Truog Test Solution.**—200 grams of neutral calcium chloride are dissolved is water, 25 grams of neutral zinc sulphide (Merck's B. L. Reagent) added, and solution is diluted to 1 liter.

**Lead Acetate Paper.**—Filter paper is soaked in 10% lead acetate, dried in oven at 90° C. and cut into half-inch strips.

**Standard Calcium Hydrate Solution.**—N/50 $Ca(OH)_2$ solution prepared and preserved in bottle fitted with soda-lime guard tube. One cc. is equivalent to 200 pounds $CaCO_3$ requirement on 2,000,000 pounds of soil.

**Phenolphthalein Indicator.**—5% solution of phenolphthalein in 95% alcohol.

[1] Jour. Am. Chem. Soc., Vol. 26, p. 661.
[2] Bulletin 249, Wisconsin Agr. Exp. Sta.

### Procedure.

To 10 grams of 2-mm. soil in 300-cc. Erlenmeyer flask are added 5 cc. of Truog test solution and 95 cc. of water. Contents of flask are shaken and brought to boiling and boiled one minute, when a dry strip of lead acetate paper is laid on the mouth of flask and boiling continued for two minutes. The darkening produced on the paper is then compared with the test paper chart and the number of cubic centimeters of N/50 $Ca(OH)_2$ required to neutralize a 10-gram sample estimated. Five 10-gram samples of 2-mm. soil are weighed and treated in porcelain evaporating dishes with such amounts of N/50 $Ca(OH)_2$ that they form a series from 2 cc. below the estimated amount to 2 cc. above this amount, each member of the series varying by 1 cc. from the next. These are immediately evaporated to dryness, taken up with water and transferred to a 300-cc. flask. The volume should be about 150 cc. After shaking frequently for one hour, the flasks are allowed to stand over night and 50 cc. of the supernatant liquid of each is transferred to a small beaker. Phenolphthalein is added and the contents of the beaker are boiled to one-third their original volume. By noting which solutions in the series turn pink, the lime requirement is estimated to within 100 pounds of calcium carbonate. One cc. N/50 $Ca(OH)_2$ equals 200 pounds calcium carbonate requirement on 2,000,000 pounds of soil.

## DETERMINATION OF NITRATE NITROGEN.

### Reagents.

**Phenol-di-sulphonic Acid.**—75 grams of pure crystallized phenol are mixed with 920 grams (500 cc.) of concentrated $H_2SO_4$ (sp. gr. 1.84) and heated for six hours at 100° C. by placing the lightly stoppered flask in boiling water. Acid so prepared is stored in brown glass bottle.

**Standard Color Solution.**—A solution containing 0.1 mg. N per cc. is prepared by dissolving 0.7215 gram dried c. p. $KNO_3$ in water and diluting to one liter. One hundred cc. of this solution are removed and diluted to 1 liter. This solution contains .01 mg. N as nitrate per cc. The color standard is prepared by evaporating 10 cc. of the solution, treating with phenol-di-sulphonic acid and proceeding as in the following method.

### Procedure.

One hundred grams of 2-mm. soil, together with 1 gram $CuSO_4$ and exactly 250 cc. distilled nitrate-free water are placed in dry soil-shaking bottle. This is stoppered and shaken in shaking machine for 30 minutes. Bottle is removed and allowed to stand over night, when 75 cc. of the clear supernatant liquid are pipetted into a dry flask. Five-tenths gram of powdered MgO is added and the mixture heated to 60° C. with occasional shaking. The flask is closed with a rubber stopper and allowed to cool with further shaking. The solution is filtered through a dry filter into a dry flask, the first few cc. of filtrate being discarded. Ten cc. of clear filtrate are evaporated on the water bath in porcelain dish. The residue is treated with 2 cc. of phenol-di-sulphonic acid and mixed thoroughly by scratching with a glass rod. After 10 minutes 15 cc. of water are added, followed by enough $NH_4OH$ (1 : 1) to produce a yellow color, and the solution is transferred to a 250 cc. flask and made up to the mark. This is shaken and, if not perfectly clear, the solution is filtered. The solution is compared in a Dubosc colorimeter with the standard color solution and the result calculated as follows:

Mg. of N as nitrate per 100 grams soil = 0.05 × reading on scale of standard solution (unknown being set at 50 on scale or calculated to that amount).

## DETERMINATION OF AMMONIUM NITROGEN[1].

### Solutions.

Standard acid and alkali solutions required as for total nitrogen.

### Procedure.

One hundred grams of 2-mm. soil are placed together with 5 grams of magnesium oxide, 300 cc. of water, and a few drops of hydrocarbon oil in a liter copper distillation flask. The mixture is distilled into 10 cc. of 5/14 normal $H_2SO_4$ until the distillate measures 250 cc. The distillate is boiled and titrated after cooling with N/14 NaOH, using alizarin red indicator. One cc. N/14 NaOH = 1 milligram of nitrogen.

[1] This method is not recommended for absolute amounts of ammonia but has been found very satisfactory for determining relative amounts.

Bulletin 160 August, 1916

College of Agriculture
University of Illinois

West Virginia University
Agricultural Experiment Station
MORGANTOWN

DEPARTMENT OF SOILS

# THE RESIDUAL EFFECTS OF FERTILIZERS

BY
Firman E. Bear and Robert M. Salter

Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

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†In co-operation with the University of Chicago.
*In co-operation with the United States Department of Agriculture.

## CONCLUSIONS.

These conclusions are summarized from analyses of fertilizer plots at the West Virginia Agricultural Experiment Station which have been under experiment for the last fifteen years.

1. Nitrogen fixation from the air averaging 20 pounds per acre per year has taken place on the plot receiving acid phosphate. On the plot on which acid phosphate and sulphate of potash have been applied, the fixation of nitrogen amounted to 78 pounds per acre per year.

2. The phosphorus applied to the soil in excess of the needs of the crops was not lost in the drainage water but was fixed in the surface 6⅔ inches of soil.

3. Organic matter has been maintained and increased by the use of fertilizers without plowing under green manuring crops or crop residues other than the stubble left behind after the crops were harvested.

4. The use of quicklime in excess of the needs of the soil has caused a loss of nitrogen, phosphorus, and organic matter from the surface soil considerably larger than the increased yields produced would justify.

5. The use of manure or fertilizers (with the exception of sulphate of potash) has had a tendency to decrease the acidity of the soil.

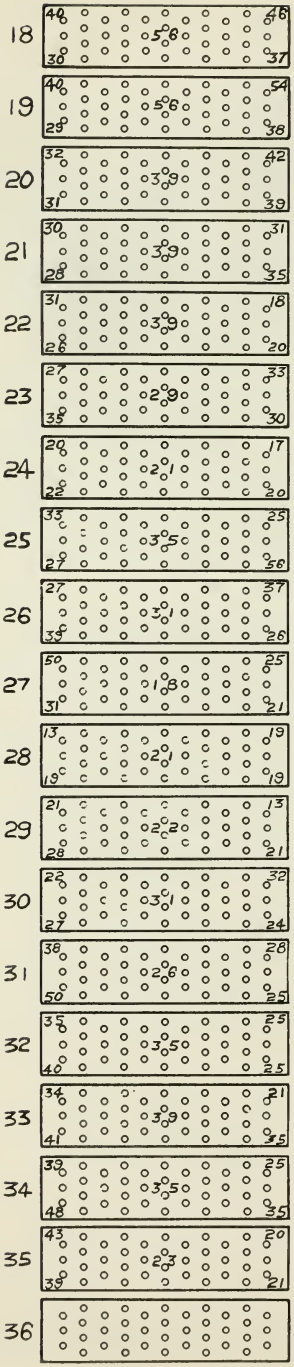



**DIAGRAM I.—Fertility Plots,** (one-tenth acre each). This diagram shows the points at which samples were chosen for a composite sample of the soil of each plot and also the depth of the underlying rock at five points.

# The Residual Effects of Fertilizers†

By FIRMAN E. BEAR and ROBERT M. SALTER.

## INTRODUCTION.

In a previous publication* of the West Virginia Agricultural Experiment Station may be found a summary of the results obtained by the experimental use of fertilizers on the Experiment Station farm. It is the purpose of this bulletin to present for consideration the effects on the soil of these fertilizer treatments and of the crops produced as a result of the use of the fertilizers, in so far as we have been able to measure these effects by laboratory methods.

## HISTORY OF THE EXPERIMENTS.

During the summer of 1900 a series of 19 tenth-acre plots was set aside at the Experiment Station farm for work with fertilizers. Each plot was made two rods wide and eight rods long. A three-foot space was left between plots. These plots were numbered serially from 18 to 36. Every third plot was left unfertilized. Accordingly, plots 18, 21, 24, 27, 30, 33, and 36 are check plots. Three of these check plots, 18, 24, and 36, are no longer satisfactory checks. The tile drain passing near plot 18 became stopped up and the yields on one end of the plot were somewhat abnormal. Plot 24 accidentally received an application of manure intended for plot 25. The manure was raked off with a hand rake a few days later but the leachings from the manure materially increased the productive power of the soil. Plot 36 was discarded because of its tendency to wash. Plots 18 and 36 have been cropped each year and have never received any fertilizer. Their present productivity corresponds rather closely to that of plots 21 and 33 so that the present condition of these plots is practically the same as though they had been checks, although complete records of their yields are not available.

†Credit is due M. F. Morgan and E. B. Wells for assistance in securing samples and in doing part of the analytical work.

*Bear, Firman E., Experiments with Fertilizers, West Virginia Agricultural Experiment Station, Bulletin 155, 1915.

## THE SOIL.

The United States Bureau of Soils has mapped the soil on the Experiment Station farm as Dekalb silt loam. It is a residual soil formed by the disintegration of grayish shales and sandstones overlying the Pittsburgh vein of coal. The depth of the underlying rock varies from 18 to 56 inches. The diagram on page 4 shows the depths of the rock at five points in each plot. The variation in the depths of the rock may have had some influence on the productivity of the plots under various treatments although we have no evidence to this effect.

The soil is of a grayish yellow color with a yellowish subsoil. The original timber was largely oak and chestnut. At the time the experiments were begun the productivity of the soil was very low. The vegetation consisted principally of red top, yarrow, poverty grass, and sorrel together with some broomsedge.

## THE CROPS GROWN.

No definite rotation of crops has been followed. Rye was grown in 1900 and 1907; wheat in 1901 and 1914; clover in 1902, 1909, and 1915; corn in 1903, 1905, and 1912; cowpeas in 1904; potatoes in 1906; timothy in 1909, 1910, and 1911; oats in 1913. A complete record of the crop yields calculated to the acre basis will be found on pages 7 and 8.

TABLE I.—Pounds of Produce per Acre.

| Plot | Fertilizer | 1900 Rye Grain | 1900 Rye Straw | 1901 Wheat Grain | 1901 Wheat Straw | 1902 Clover Hay | 1903 Corn Grain | 1903 Corn Stover | 1904 Cowpeas Hay | 1905 Corn Ensilage | 1906 Potatoes Tubers | 1907* Rye Grain | 1907* Rye Straw |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | N, K, P, CaO | 2076 | 3524 | †1665 | †3760 | 6700 | 6200 | 6800 | 6950 | 27700 | 6120 | 1170 | 3030 |
| 20 | M, CaO | 1578 | 2762 | 1840 | 4560 | 8850 | 7700 | 9400 | 6750 | 34700 | 13060 | 2140 | 4860 |
| 21 | Check | 1186 | 2064 | 1140 | 1160 | 2050 | 2000 | 3800 | 1250 | 11200 | 2600 | 140 | 360 |
| 22 | CaO | 1077 | 1813 | 1010 | 1490 | 1500 | 1620 | 3200 | 1200 | 9800 | 1520 | †130 | †330 |
| 23 | M(ash), N | 2095 | 4845 | 1880 | 3320 | 7900 | 4410 | 5800 | 2750 | 15300 | 2500 | 170 | 280 |
| 24 | Check | 1100 | 2070 | 1070 | 1830 | 2100 | 1770 | 3650 | 1350 | 12100 | 2610 | 140 | 380 |
| 25 | M | 1913 | 3587 | 1920 | 4580 | 9550 | 5230 | 6500 | 6100 | 34800 | 11300 | 1880 | 4420 |
| 26 | N, K, P | 2463 | 4317 | 1750 | 3950 | 7250 | 5620 | 7000 | 6300 | 29000 | 7030 | 1170 | 2530 |
| 27 | Check | 1297 | 2583 | 1120 | 1780 | 2850 | 1980 | 3450 | 2200 | 12500 | 2850 | 160 | 290 |
| 28 | P, K | 1411 | 2739 | 1550 | 3350 | 5500 | 5160 | 6200 | 4400 | 16100 | 6360 | 850 | 1850 |
| 29 | N, K | 1980 | 3560 | 1080 | 1820 | 2000 | 1500 | 3300 | 2300 | 15000 | 3520 | 140 | 260 |
| 30 | Check | 1340 | 2540 | 1050 | 1650 | 2650 | 1820 | 3600 | 2100 | 10900 | 2140 | 160 | 250 |
| 31 | N, P | 2267 | 4153 | 1550 | 3350 | 7900 | 5400 | 7000 | 5150 | 18900 | 3830 | 1030 | 2270 |
| 32 | K | 1402 | 2678 | 1030 | 1670 | 2500 | 2000 | 3750 | 1950 | 11800 | 2630 | 140 | 360 |
| 33 | Check | 1330 | 2600 | 1110 | 1990 | 2200 | 1930 | 3600 | 2450 | 8700 | 2400 | 120 | 280 |
| 34 | P | 1360 | 2810 | 1390 | 2610 | 5400 | 4570 | 5750 | 3650 | 14100 | 3800 | 770 | 1930 |
| 35 | N | 1914 | 3716 | 930 | 1770 | 2600 | 1330 | 3300 | 2500 | 10200 | 2250 | 210 | 290 |

*Plots were sown to timothy and clover but on account of unfavorable weather conditions gave very poor crop in 1908. Plots were mowed and hay was left on the ground.

†Calculated yields.

N, K, and P are symbols for nitrogen, potassium, and phosphorus respectively. CaO is the symbol for burned lime. M indicates manure.

**TABLE I (continued).—Pounds of Produce per Acre.**

| Plot | Fertilizer | 1909 Timothy-Clover Hay | 1910 Timothy Hay | 1911 Timothy Hay | 1912 Corn Grain | 1912 Corn Stover | 1913 Oats Grain | 1913 Oats Straw | 1914 Wheat Grain | 1914 Wheat Straw | 1915 Clover Hay | Total Produce |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | N, K, P, CaO | 5600 | 9000 | 6090 | 4630 | 4190 | 875 | 2625 | 1720 | 4380 | 5800 | 120605 |
| 20 | M, CaO | 6800 | 10400 | 6240 | 5010 | 4600 | 1250 | 6000 | 1080 | 5420 | 7400 | 152400 |
| 21 | Check | 755 | 1305 | 1130 | 1500 | 2900 | 220 | 680 | 350 | 710 | 100 | 38600 |
| 22 | CaO | 535 | 1240 | 1100 | 2470 | 3080 | 250 | 650 | 580 | 1270 | 750 | 36615 |
| 23 | M(ash), N | 490 | 1120 | 890 | 3550 | 4620 | 530 | 1170 | 1490 | 3060 | 2100 | 69270 |
| 24 | Check | 535 | 1180 | 900 | 1330 | 1400 | 280 | 420 | *1190 | *3010 | *2660 | 43075 |
| 25 | M | 7800 | 9000 | 6640 | 4800 | 4400 | 1040 | 3760 | 1380 | 3420 | 5650 | 139670 |
| 26 | N, K, P | 4700 | 8700 | 6090 | 4890 | 4450 | 800 | 1800 | 1590 | 3460 | 3250 | 117910 |
| 27 | Check | 505 | 1275 | 850 | 1550 | 2900 | 250 | 400 | 370 | 780 | 230 | 42170 |
| 28 | P, K | 1640 | 3475 | 2280 | 3170 | 4020 | 620 | 1130 | 1230 | 2520 | 1440 | 76995 |
| 29 | N, K | 2125 | 3880 | 2390 | 2050 | 2300 | 380 | 820 | 560 | 890 | 360 | 52215 |
| 30 | Check | 705 | 1375 | 930 | 1900 | 1990 | 290 | 710 | 370 | 780 | 230 | 39480 |
| 31 | N, P | 4500 | 7300 | 4320 | 4080 | 4200 | 790 | 1410 | 1500 | 2450 | 2590 | 95940 |
| 32 | K | 430 | 1285 | 850 | 2330 | 2400 | 330 | 570 | 380 | 820 | 260 | 41565 |
| 33 | Check | 305 | 1260 | 570 | 1900 | 1920 | 300 | 550 | 330 | 770 | 230 | 36845 |
| 34 | P | 845 | 3410 | 2290 | 2100 | 2050 | 750 | 1250 | 560 | 990 | 1030 | 63415 |
| 35 | N | 720 | 2885 | 1740 | 1400 | 1380 | 330 | 470 | 340 | 760 | 160 | 41195 |

*Abnormal yields due to an accidental application of manure which was subsequently removed with a hand rake.

## FERTILIZER TREATMENTS.

Much heavier applications of fertilizers have been made during the fifteen years that have elapsed since the beginning of the experiment than would be used in actual practice. This was done in order to magnify the effect and to shorten the period of time necessary to produce a measurable effect on the soil. The following amounts of fertilizers have been applied annually to the plots with the exceptions noted:

Plots 18, 21, 24, 27, 30, 33, and 36. No fertilizer.

Plot 19. 40 pounds sodium nitrate; 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906); 100 pounds lime in 1900; 150 pounds lime in 1906; and 200 pounds lime in 1912.

Plot 20. Two tons stable manure; 100 pounds lime in 1900; 150 pounds lime in 1906; and 200 pounds lime in 1912.

Plot 22. 100 pounds lime in 1900 and in 1903; 150 pounds in 1906; and 200 pounds in 1912.

Plot 23. Ash from two tons of stable manure, together with an amount of nitrogen in the form of sodium nitrate equivalent to the nitrogen originally present in the stable manure. Applications made in 1900 and in 1901. Since then no further applications have been made until 1912 when it received 40 pounds of a 4-16-4 fertilizer.

Plot 25. Two tons stable manure applied annually except in 1903.

Plot 26. 40 pounds sodium nitrate; 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906).

Plot 28. 40 pounds acid phosphate; 15 pounds potassium sulphate (20 pounds in 1906).

Plot 29. 40 pounds sodium nitrate; 15 pounds potassium sulphate (20 pounds in 1906).

Plot 31. 40 pounds acid phosphate; 40 pounds sodium nitrate.

Plot 32. 15 pounds potassium sulphate (20 pounds in 1906).

Plot 34. 40 pounds acid phosphate.

Plot 35. 40 pounds sodium nitrate.

In 1902, 1907, 1908, 1914, and 1915 no fertilizer was applied on any of the plots. In 1913 only one-half of the original application of fertilizer was given.

**TABLE II.—Total Amounts of Fertilizers Applied per Acre from 1900 to 1915 Inclusive.**

| Plot | Nitrate of Soda, Pounds per Acre | Acid Phosphate, Pounds per Acre | Sulphate of Potash, Pounds per Acre | Lime, Pounds per Acre | Manure, Tons per Acre |
|---|---|---|---|---|---|
| 19 | 4200 | 4200 | 1625 | 4500 | ..... |
| 20 | ..... | ..... | ..... | 4500 | 210 |
| 21 | ..... | ..... | ..... | ..... | ..... |
| 22 | ..... | ..... | ..... | 5500 | ..... |
| 23 | 300 | Ash of 40 tons of manure until 1912 | | ..... | ..... |
| 24 | ..... | ..... | ..... | ..... | ..... |
| 25 | ..... | ..... | ..... | ..... | 190 |
| 26 | 4200 | 4200 | 1625 | ..... | ..... |
| 27 | ..... | ..... | ..... | ..... | ..... |
| 28 | ..... | 4200 | 1625 | ..... | ..... |
| 29 | 4200 | ..... | 1625 | ..... | ..... |
| 30 | ..... | ..... | ..... | ..... | ..... |
| 31 | 4200 | 4200 | ..... | ..... | ..... |
| 32 | ..... | ..... | 1625 | ..... | ..... |
| 33 | ..... | ..... | ..... | ..... | ..... |
| 34 | ..... | 4200 | ..... | ..... | ..... |
| 35 | 4200 | ..... | ..... | ..... | ..... |

## THE EFFECTS OF THE FERTILIZERS ON THE CROPS.

The record of the crop yields shows some very interesting effects. The total produce per acre has varied from 36,615 pounds on the plot receiving burned lime to 152,400 pounds on the plot receiving manure and lime. We are particularly interested in the yields in calculating the elements of plant food which have been removed from the soil by the crops grown. Unfortunately no analyses have been made of the crops from the various plots. We are compelled, therefore, to base our calculations on average analyses of these crops. We have chosen the analyses as given by Hopkins* with a few exceptions in which analyses given by Henry and Morrison† were more nearly comparable.

*Soil Fertility and Permanent Agriculture

†Feeds and Feeding.

TABLE III.—Pounds of nitrogen, phosphorus, and potassium removed by crops from fertility plots since 1900, calculated on the acre basis.

| Plot | Treatment | N | P | K |
|---|---|---|---|---|
| 19 | N, P, K, CaO | 1146 | 177 | 964 |
| 20 | M, CaO | 1382 | 213 | 1213 |
| 21 | Check | 313 | 55 | 279 |
| 22 | CaO | 312 | 57 | 235 |
| 23 | M(ash), N | 687 | 109 | 538 |
| 24 | Check | 378 | 60 | 306 |
| 25 | M | 1278 | 195 | 1098 |
| 26 | N, P, K | 1082 | 171 | 916 |
| 27 | Check | 351 | 59 | 304 |
| 28 | P, K | 705 | 115 | 587 |
| 29 | N, K | 417 | 73 | 385 |
| 30 | Check | 341 | 57 | 290 |
| 31 | N, P | 945 | 148 | 799 |
| 32 | K | 349 | 60 | 296 |
| 33 | Check | 321 | 55 | 271 |
| 34 | P | 591 | 95 | 490 |
| 35 | N | 356 | 61 | 312 |

TABLE IV.—Pounds of nitrogen, phosphorus, and potassium, calculated from check plots, which would have been removed per acre in crops if no fertilizer had been applied.

| Plot | N | P | K |
|---|---|---|---|
| 19 | 313 | 55 | 279 |
| 20 | 313 | 55 | 279 |
| 21 | 313 | 55 | 279 |
| 22 | 319 | 56 | 283 |
| 23 | 326 | 56 | 287 |
| 24 | 332 | 57 | 292 |
| 25 | 338 | 58 | 296 |
| 26 | 345 | 58 | 300 |
| 27 | 351 | 59 | 304 |
| 28 | 347 | 58 | 299 |
| 29 | 343 | 57 | 295 |
| 30 | 341 | 57 | 290 |
| 31 | 334 | 56 | 284 |
| 32 | 328 | 55 | 277 |
| 33 | 321 | 55 | 271 |
| 34 | 321 | 55 | 271 |
| 35 | 321 | 55 | 271 |

Table V gives the amounts of nitrogen, phosphorus, and potassium removed from the soil of each plot by the increased crops according to these analyses, and also the number of pounds of these elements supplied in the fertilizers used. The columns headed "Gain or Loss" represent the relative conditions of the various plots as they would be if there had been no losses in the drainage water or no gains from the air.

TABLE V.—Calculated Gain or Loss in Nitrogen, Phosphorus, and Potassium.

| Plot | Treatment | Nitrogen | | | Phosphorus | | | Potassium | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Removed in Increased Crops | Added in Fertilizer | Gain or Loss | *Removed in Increased Crops | Added in Fertilizer | Gain or Loss | *Removed in Increased Crops | Added in Fertilizer | Gain or Loss |
| 19 | N, P, K, CaO | 833 | 672 | —161 | 122 | 293 | +171 | 685 | 675 | — 10 |
| 20 | M, CaO | 1069 | ? | ? | 158 | ? | ? | 934 | ? | ? |
| 22 | CaO | — 7 | ..... | + 7 | 1 | ..... | — 1 | —48 | ..... | + 48 |
| 23 | M(ash), N | 361 | ? | ? | 53 | ? | ? | 251 | ? | ? |
| 25 | M | 940 | ? | ? | 137 | ? | ? | 802 | ? | ? |
| 26 | N, P, K | 737 | 672 | — 65 | 113 | 293 | +180 | 616 | 675 | + 59 |
| 28 | P, K | 358 | ..... | —358 | 57 | 293 | +236 | 288 | 675 | +387 |
| 29 | N, K | 74 | 672 | +598 | 16 | ..... | — 16 | 90 | 675 | +585 |
| 31 | N, P | 611 | 672 | + 61 | 92 | 293 | +201 | 515 | ..... | —515 |
| 32 | K | 21 | ..... | — 21 | 5 | ..... | — 5 | 19 | 675 | +656 |
| 34 | P | 270 | ..... | —270 | 40 | 293 | +253 | 219 | ..... | —219 |
| 35 | N | 35 | 672 | +637 | 6 | ..... | — 6 | 41 | ..... | — 41 |

*Calculated from Tables III and IV.

## ANALYTICAL DATA.

During the spring of 1915 the plots were sampled by the use of a soil auger. Thirty-eight borings each to a depth of 6⅔ inches were taken for a composite sample of soil on each plot. These borings were distributed over the plots as shown in the diagram on page 4. The samples were air dried and put through a 2-mm. sieve to remove stones and undecomposed pieces of organic matter. After thorough mixing a sufficient amount of this composite sample was chosen for analytical purposes and pulverized to pass a sieve with 100 meshes to the inch. Samples of the subsoil from 6⅔ to 20 inches were also taken and prepared for analysis.

It was thought desirable to determine the probable error in sampling a plot. Accordingly six composite samples of 38 borings each were chosen from plot 26 and prepared for analysis. A record of the total carbon, nitrogen, and phosphorus as found in these six samples is given below:

**TABLE VI.—Percentages of carbon, nitrogen, and phosphorus in a soil as determined by duplicate analyses of six composite samples from the same plot.**

| Sample | Total Carbon | | Total Nitrogen | | Total Phosphorus | |
|---|---|---|---|---|---|---|
| | Analysis A | Analysis B | Analysis A | Analysis B | Analysis A | Analysis B |
| 1 | 1.53 | 1.51 | .130 | .129 | .045 | .045 |
| 2 | 1.55 | 1.56 | .138 | .138 | .047 | .046 |
| 3 | 1.51 | 1.49 | .134 | .133 | .046 | .046 |
| 4 | 1.52 | 1.54 | .133 | .133 | .045 | .045 |
| 5 | 1.64 | 1.64 | .148 | .147 | .048 | .049 |
| 6 | 1.52 | 1.52 | .135 | .135 | .045 | .046 |

It will be seen from the table that there is a very close agreement among five of the six samples. No explanation is available for the differences to be noticed in sample 5. However, these differences necessitate a more careful study of the results to follow in order to be sure that the conclusions drawn are correct.

## TABLE VII.—Analyses of Composite Samples of Surface Soil from Fertility Plots.

| Plot No. | Treatment | Percent of Air Dry Soil | | | | | | | | | | | | Lbs. $CaCO_3$ Requirement | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fe | Ti | Al | Mn | Ca | Mg | K | S | P | N A* | N B† | C | A* | B† |
| 18 | Check | ..... | ..... | ..... | ..... | ..... | ..... | 1.25 | ..... | 0.030 | 0.097 | 0.054 | 1.19 | | |
| | | ..... | ..... | ..... | ..... | ..... | ..... | 1.26 | ..... | 0.030 | 0.098 | 0.055 | 1.20 | 2800 | 6800 |
| 19 | N, P, K, CaO | 1.91 | 0.79 | 4.22 | 0.22 | 0.21 | 0.19 | 1.23 | .062 | 0.037 | 0.106 | 0.066 | 1.23 | | |
| | | 1.92 | 0.74 | 4.15 | 0.22 | 0.21 | 0.19 | 1.21 | .063 | 0.037 | 0.107 | 0.066 | 1.22 | 0 | 3600 |
| 20 | M, CaO | 1.94 | 0.72 | 4.01 | 0.21 | 0.23 | 0.20 | 1.24 | .063 | 0.053 | 0.135 | 0.066 | 1.63 | | |
| | | 1.90 | 0.72 | 4.00 | 0.22 | 0.22 | 0.20 | 1.24 | .062 | 0.052 | 0.135 | 0.066 | 1.62 | 0 | 2800 |
| 21 | Check | 1.94 | 0.76 | 4.30 | 0.24 | 0.11 | 0.22 | 1.21 | .062 | 0.030 | 0.092 | 0.054 | 1.06 | | |
| | | 1.94 | 0.68 | 4.39 | 0.23 | 0.12 | 0.21 | 1.21 | .060 | 0.029 | 0.091 | 0.054 | 1.06 | 2800 | 5600 |
| 22 | CaO | 2.06 | 0.77 | 4.29 | 0.18 | 0.24 | 0.21 | 1.26 | .048 | 0.026 | 0.088 | 0.051 | 0.97 | | |
| | | 2.04 | 0.73 | 4.37 | 0.19 | 0.26 | 0.22 | 1.28 | .044 | 0.026 | 0.088 | 0.051 | 0.97 | 0 | 3600 |
| 23 | M(ash), N | 2.18 | 0.74 | 4.48 | 0.18 | 0.14 | 0.22 | 1.29 | .053 | 0.033 | 0.097 | 0.059 | 1.03 | | |
| | | 2.17 | 0.72 | 4.45 | 0.18 | 0.13 | 0.23 | 1.28 | .055 | 0.033 | 0.097 | 0.058 | 1.04 | 2800 | 6000 |
| 24 | Check | 2.60 | 0.71 | 4.77 | 0.19 | 0.14 | 0.26 | 1.41 | .058 | 0.035 | 0.102 | 0.058 | 1.04 | | |
| | | 2.59 | 0.70 | 4.77 | 0.18 | 0.13 | 0.28 | 1.40 | .062 | 0.035 | 0.102 | 0.058 | 1.04 | 3000 | 3600 |
| 25 | M | 2.35 | 0.70 | 4.72 | 0.28 | 0.14 | 0.24 | 1.29 | .071 | 0.061 | 0.162 | 0.067 | 1.84 | | |
| | | 2.33 | 0.70 | 4.71 | 0.27 | 0.15 | 0.25 | 1.29 | .075 | 0.061 | 0.162 | 0.066 | 1.84 | 2800 | 3200 |
| 26 | N, P, K | 1.82 | 0.69 | 4.43 | 0.27 | 0.11 | 0.19 | 1.27 | .070 | 0.045 | 0.133 | 0.064 | 1.53 | | |
| | | 1.85 | 0.69 | 4.47 | 0.25 | 0.11 | 0.20 | 1.28 | .065 | 0.045 | 0.133 | 0.065 | 1.51 | 3200 | 4400 |
| 27 | Check | 1.77 | 0.70 | 4.44 | 0.19 | 0.13 | 0.20 | 1.21 | .064 | 0.030 | 0.098 | 0.057 | 1.10 | | |
| | | 1.76 | 0.70 | 4.49 | 0.20 | 0.12 | 0.20 | 1.23 | .062 | 0.031 | 0.098 | 0.057 | 1.09 | 3800 | 5200 |
| 28 | P, K | 1.80 | 0.70 | 4.45 | 0.26 | 0.13 | 0.20 | 1.28 | .070 | 0.043 | 0.114 | 0.073 | 1.31 | | |
| | | 1.79 | 0.70 | 4.51 | 0.25 | 0.13 | 0.20 | 1.28 | .071 | 0.043 | 0.114 | 0.073 | 1.29 | 3600 | 5200 |
| 29 | N, K | 1.89 | 0.70 | 4.57 | 0.27 | 0.11 | 0.20 | 1.28 | .066 | 0.032 | 0.115 | 0.067 | 1.35 | | |
| | | 1.89 | 0.71 | 4.50 | 0.28 | 0.11 | 0.19 | 1.28 | .063 | 0.032 | 0.115 | 0.067 | 1.35 | 3400 | 5200 |
| 30 | Check | 2.00 | 0.67 | 4.78 | 0.22 | 0.13 | 0.19 | 1.30 | .066 | 0.035 | 0.113 | 0.059 | 1.31 | | |
| | | 2.00 | 0.67 | 4.76 | 0.25 | 0.13 | 0.17 | 1.30 | .071 | 0.035 | 0.114 | 0.060 | 1.32 | 3800 | 5600 |
| 31 | N, P | 2.00 | 0.68 | 4.77 | 0.19 | 0.15 | 0.19 | 1.35 | .058 | 0.044 | 0.120 | 0.064 | 1.41 | | |
| | | 2.04 | 0.68 | 4.78 | 0.21 | 0.14 | 0.20 | 1.35 | .062 | 0.044 | 0.120 | 0.065 | 1.39 | 3200 | 5200 |
| 32 | K | 2.18 | 0.73 | 4.82 | 0.28 | 0.13 | 0.20 | 1.33 | .071 | 0.036 | 0.115 | 0.059 | 1.46 | | |
| | | 2.14 | 0.72 | 4.84 | 0.28 | 0.11 | 0.21 | 1.34 | .066 | 0.036 | 0.116 | 0.059 | 1.46 | 3600 | 5600 |
| 33 | Check | 2.23 | 0.72 | 5.24 | 0.25 | 0.12 | 0.20 | 1.37 | .069 | 0.037 | 0.115 | 0.063 | 1.37 | | |
| | | 2.16 | 0.72 | 5.27 | 0.25 | 0.12 | 0.20 | 1.34 | .070 | 0.037 | 0.115 | 0.063 | 1.37 | 3600 | 5200 |
| 34 | P | 2.27 | 0.73 | 5.24 | 0.22 | 0.13 | 0.22 | 1.34 | .063 | 0.044 | 0.115 | 0.059 | 1.41 | | |
| | | 2.28 | 0.73 | 5.16 | 0.22 | 0.13 | 0.23 | 1.36 | .066 | 0.044 | 0.115 | 0.060 | 1.41 | 3400 | 5600 |
| 35 | N | 2.21 | 0.73 | 5.11 | 0.18 | 0.13 | 0.19 | 1.33 | .070 | 0.031 | 0.113 | 0.049 | 1.44 | | |
| | | 2.16 | 0.72 | 5.19 | 0.22 | 0.13 | 0.20 | 1.35 | .067 | 0.031 | 0.113 | 0.049 | 1.44 | 3400 | 5600 |
| 36 | Check | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.032 | 0.104 | 0.055 | 1.22 | | |
| | | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.032 | 0.104 | 0.055 | 1.22 | | |

*Surface soil to 6⅔ inches.
†Subsoil, 6⅔ to 20 inches.

## INTERPRETATION OF ANALYSES.

### Analyses of Check Plots.

The analyses of the check plots indicate that the fertility increases as we proceed from plot 21 to plot 33, and then decreases from 33 to 36. Plot 18 shows a slightly higher content of nitrogen and carbon than plot 21. It must be remembered that plot 24 is no longer a check, having accidentally received an application of manure. Any calculations as to the effect of fertilizers applied on the present composition of the soil must take into consideration this gradual increase in the plant food content of these soils from one end of the series to the other. By dividing the differences in the analyses of the check plots by the number of plots between the checks we are able to calculate what the plant food content of each of the plots would have been at the present time if it had received no fertilizer. Table VIII shows the results of this calculation on the basis of pounds of elements per 2,000,000 pounds of surface soil and 4,000,000 pounds of subsoil.

**TABLE VIII.—Present Analyses of Plots as Calculated from Check Plots Had no Fertilizer or Manure Been Applied. (Pounds per Acre of 2,000,000 Pounds of Surface Soil or 4,000,000 Pounds of Subsoil.)**

| Plot No. | Nitrogen A* | Nitrogen B† | Phosphorus | Carbon | $CaCO_3$ Requirement A* Lbs. | $CaCO_3$ Requirement B† Lbs. |
|---|---|---|---|---|---|---|
| 18 | 1960 | 2180 | 600 | 23,900 | 2800 | 6800 |
| 19 | 1917 | 2174 | 597 | 23,000 | 2800 | 3600 |
| 20 | 1873 | 2166 | 593 | 22,100 | 2800 | 2800 |
| 21 | 1830 | 2160 | 590 | 21,200 | 2800 | 5600 |
| 22 | 1852 | 2180 | 593 | 21,317 | 2967 | 3600 |
| 23 | 1873 | 2200 | 597 | 21,433 | 3133 | 6000 |
| 24 | 1895 | 2220 | 600 | 21,550 | 3300 | 3600 |
| 25 | 1917 | 2240 | 603 | 21,667 | 3467 | 3200 |
| 26 | 1938 | 2260 | 607 | 21,783 | 3633 | 4400 |
| 27 | 1960 | 2280 | 610 | 21,900 | 3800 | 5200 |
| 28 | 2063 | 2314 | 640 | 23,367 | 3800 | 5200 |
| 29 | 2166 | 2346 | 670 | 24,833 | 3800 | 5200 |
| 30 | 2270 | 2380 | 700 | 26,300 | 3800 | 5600 |
| 31 | 2280 | 2426 | 713 | 26,667 | 3733 | 5200 |
| 32 | 2290 | 2474 | 727 | 27,033 | 3667 | 5600 |
| 33 | 2300 | 2520 | 740 | 27,400 | 3600 | 5200 |
| 34 | 2227 | 2420 | 707 | 26,400 | 3600 | 5600 |
| 35 | 2153 | 2320 | 673 | 25,400 | 3600 | 5600 |
| 36 | 2080 | 2220 | 640 | 24,400 | ..... | ..... |

*Surface soil to 6⅔ inches.
†Subsoil, 6⅔ to 20 inches.

## The Nitrogen Balance.

Every plot which has received an application of acid phosphate shows a higher content of nitrogen than it should, according to the calculations as given in Table IX. In every case the amount of nitrogen present is in excess of what it should be if there had been no application of nitrogen other than that in nitrate of soda. The data seem to indicate that nitrogen has been secured from the air through the growth of legumes or otherwise. Even on the check plots the nitrogen content is apparently as high as it was fifteen years ago when the experiment was begun. Analyses made at that time of a composite sample chosen from eight different points over the plots showed a nitrogen content of 1900 pounds per 2,000,000 pounds of surface soil. The average nitrogen content of the check plots in 1915 was 2042 pounds per 2,000,000.

It will be noticed that the plot receiving only nitrate of soda has suffered a loss of 890 pounds of nitrogen although the amount of nitrogen added was only 672 pounds. By comparing this plot with the one receiving sulphate of potash and nitrate of soda it will be observed that the loss is considerably reduced, being only 138 pounds. Plots 31, receiving nitrate of soda and acid phosphate, shows a gain of 213 pounds. One is led to infer from this that acid phosphate and sulphate of potash have in some way either prevented this loss or have been responsible in some way for an accumulation of nitrogen sufficient to offset this loss. Plot 26, receiving an application of acid phosphate and sulphate of potash, shows an increase amounting to 1173 pounds per acre.

The evidence seems to be sufficient to justify the statement that there has been a nitrogen fixation in the soil on the plots receiving acid phosphate and sulphate of potash varying from 20 pounds per acre per year, on the plot receiving acid phosphate alone, to 78 pounds per acre per year on the plot receiving acid phosphate and sulphate of potash. Table IX shows the amount of nitrogen fixed on the various plots since 1900, figured on the basis of an acre of soil to a depth of 20 inches and weighing 6,000,000 pounds. Of course it may be possible that the crops contained more nitrogen than the analyses given in Table III would indicate, but even so, we have not taken into consideration the loss of nitrogen in the drainage water which in the case of plots receiving nitrate of soda must have been considerable. The analyses of the drainage water from Broadbalk field at Rothamsted* indicate

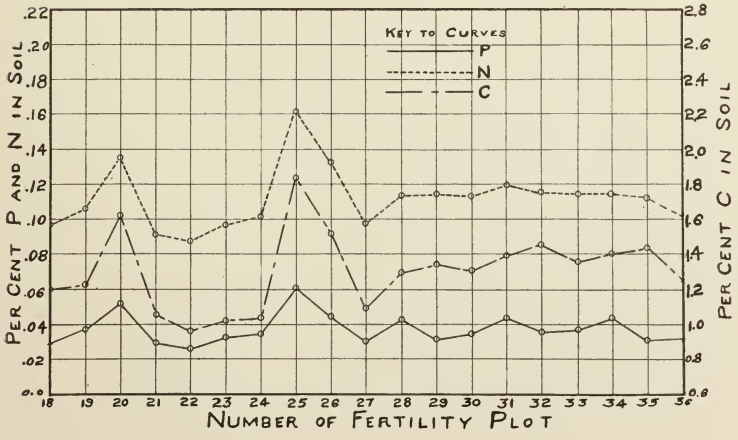
*Hall, The Soil, p. 201.

that this must have been true. The soil on the Experiment Station farm overlies sandstone and is very well drained. Plots receiving nitrogen but no phosphorus show a serious loss of nitrogen. Only three legumes have been grown on the plots during the experiment and these crops were removed from the plots, so that most of the nitrogen fixation must have been brough about by some other agency. Azotobacter chroococcum and Clostridium pasteurianum are both present in the soil of the fertility plots.

Either acid phosphate or sulphate of potash has been of value in aiding nitrogen fixation but a combination of both has been considerably more effective than either applied alone.

DIAGRAM II.

CORRELATION BETWEEN TOTAL P, N, AND C IN SOIL OF FERTILITY PLOTS.



## TABLE IX.—The Nitrogen Balance. (Pounds of Nitrogen per Acre.)

| Plot No. | Treatment | From 0 to 6⅔ Inches | | | From 6⅔ to 20 Inches | | | Total Gain or Loss 0 to 20 in. | Calculated Gain or Loss‡ | Nitrogen Balance |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Nitrogen Present† | Nitrogen Calculated from Checks* | Gain or Loss | Nitrogen Present† | Nitrogen Calculated from Checks* | Gain or Loss | | | |
| 19 | N, P, K, CaO | 2130 | 1917 | +213 | 2640 | 2174 | +466 | +679 | —161 | +840 |
| 22 | CaO | 1760 | 1852 | — 92 | 2040 | 2180 | —140 | —232 | + 7 | —225 |
| 26 | N, P, K | 2660 | 1938 | +722 | 2572 | 2260 | +312 | +1034 | — 65 | +1099 |
| 28 | P, K | 2280 | 2063 | +217 | 2912 | 2314 | +598 | +815 | —358 | +1173 |
| 29 | N, K | 2300 | 2166 | +134 | 2672 | 2346 | +326 | +460 | +598 | —138 |
| 31 | N, P | 2400 | 2280 | +120 | 2580 | 2426 | +154 | +274 | + 61 | +213 |
| 32 | K | 2310 | 2290 | + 20 | 2364 | 2474 | —110 | — 90 | — 21 | — 69 |
| 34 | P | 2300 | 2227 | + 73 | 2372 | 2420 | — 48 | + 25 | —270 | +295 |
| 35 | N | 2260 | 2153 | +107 | 1960 | 2320 | —360 | +253 | +637 | —890 |

†Table VII.
*Table VIII.
‡Table V.

## The Phosphorus Balance.

Every plot which has received applications of manure or acid phosphate shows a high content of phosphorus. Apparently all or most of the phosphorus applied in the form of fertilizer which was not used by the crops is still present in the surface soil, having never diffused to any considerable extent into the subsoil. This is shown in Table X in which the actual gain in phosphorus as measured by the check plots is compared with the calculated gains as given in Table V. It will be seen that there is a rather close agreement between the two, sufficiently so to justify the statement that the phosphorus applied to the soil in excess of the needs of the crop has been fixed within the first 6⅔ inches of soil.

**TABLE X.—The Phosphorus Balance. (Pounds per 2,000,000 Pounds of Surface Soil.)**

| Plot No. | Treatment | Phosphorus Present | Phosphorus Calculated from Checks† | Gain or Loss | Calculated Gain or Loss* | Phosphorus Balance |
|---|---|---|---|---|---|---|
| 19 | N, P, K, CaO | 740 | 590 | +150 | +171 | — 21 |
| 22 | CaO | 520 | 593 | — 73 | — 1 | — 72 |
| 26 | N, P, K | 900 | 607 | +293 | +180 | +113 |
| 28 | P, K | 860 | 640 | +220 | +236 | — 16 |
| 29 | N, K | 640 | 670 | — 30 | — 16 | — 14 |
| 31 | N, P | 880 | 713 | +167 | +201 | — 34 |
| 32 | K | 720 | 727 | — 7 | — 5 | — 2 |
| 34 | P | 880 | 707 | +173 | +253 | — 80 |
| 35 | N | 620 | 673 | — 53 | — 6 | — 47 |

†See Table VIII.
*See Table V.

## The Carbon Balance.

The amounts of organic matter present in the soil on the plots vary considerably with different fertilizer treatments. There is a very close correlation in most cases between the amounts of carbon, phosphorus, and nitrogen in the various plots as shown in Diagram II. The relation between total carbon and the organic matter in the soil is not definitely known. The factor 1.724* is used frequently to estimate the organic matter from the total carbon. In all plots receiving fertilizing materials the content of organic matter is greater than in the check plots. It must be remembered that no green manuring crop or manure was applied to any of the fertilizer plots. Any increase in organic matter must have come from the roots and stubble of the crops produced. We have already shown that the content of nitrogen in the check plots is as much as or more than it was at the beginning of the experiment. We assume from the correlation between nitrogen and carbon

*Wiley, Principles and Practice of Agricultural Analysis, Vol. I.

as shown in Diagram II referred to before that the content of organic matter has remained practically constant in the check plots, and largely because the soil was so low in fertility originally that the organic matter remaining behind represented only that which was very resistant to decay. The evidence indicates that organic matter can be maintained and increased by the use of fertilizers without plowing down green crops or anything other than the stubble left behind after the crop is harvested. It will be observed that there is a considerable increase in the amount of organic matter in the soil of the plot receiving the complete fertilizer.

TABLE XI.—Carbon and Organic Matter Balance. (Pounds per 2,000,000 Pounds of Surface Soil.)

| Plot No. | Treatment | Carbon Present | Carbon Calculated from Checks† | Carbon Gain or Loss | Organic Matter* Gain or Loss |
|---|---|---|---|---|---|
| 19 | N, P, K, CaO.... | 24500 | 23000 | + 1500 | + 2586 |
| 20 | M, CaO ..... | 32500 | 22100 | +10400 | +17930 |
| 22 | CaO ..... | 19400 | 21317 | — 917 | — 1581 |
| 25 | M ..... | 36800 | 21667 | +15133 | +26089 |
| 26 | N, P, K..... | 30400 | 21783 | + 8617 | +14856 |
| 28 | P, K ..... | 26000 | 23367 | + 2633 | + 4539 |
| 29 | N, K ..... | 27000 | 24833 | + 2167 | + 3736 |
| 31 | N, P ..... | 28000 | 26667 | + 1333 | + 2298 |
| 32 | K ..... | 29200 | 27033 | + 2167 | + 3736 |
| 34 | P ..... | 28200 | 26400 | + 1800 | + 3103 |
| 35 | N ..... | 28800 | 25400 | + 3400 | + 5875 |

†Table VIII.
*Carbon x 1.724.

## THE BAD EFFECTS OF BURNED LIME.

On the plots to which lime has been applied there are certain outstanding effects which can be observed by a study of the analyses. Referring to Table I, it will be noticed that the use of lime alone has been responsible for a loss in yield as an average of the last fifteen years. When used in connection with manure or fertilizer it has produced an increase in yield. As to what this increase amounted to when applied with manure cannot be ascertained since the plot receiving manure and lime had a total of 210 tons of manure as compared to 190 tons on the plot receiving no lime. On the fertilizer plot the use of lime has produced an increase amounting to a total of 2695 pounds of produce in fifteen years, little more than sufficient to pay for the lime. However, the application of lime has caused a decrease in nitrogen, phosphorus, and carbon in the soil out of all proportion to the increased crops produced. Table XII shows this loss. In every case the application of lime has proved detrimental to the surface soil.

**TABLE XII.—Loss of Nitrogen, Phosphorus, and Carbon from Limed Plots.**
**(Pounds per 2,000,000 Pounds of Surface Soil.)**

| Plot No. | Treatment | Nitrogen | | | Phosphorus | | | Carbon | | | Organic Matter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Present | Check* | Difference | Present | Check* | Difference | Present | Check* | Difference | |
| 26 | N, P, K | 2660 | 1938 | 728 | 900 | 607 | 293 | 30400 | 21783 | 8617 | |
| 19 | N, P, K, CaO | 2130 | 1917 | 213 | 740 | 590 | 150 | 24500 | 23000 | 1500 | |
| | Loss | | | 515 | | | 143 | | | 7117 | 12270 |
| 25 | M | 3240 | 1917 | 1323 | 1220 | 603 | 617 | 36800 | 21667 | 15133 | |
| 20 | M, CaO | 2700 | 1830 | 870 | 1050 | 590 | 460 | 32500 | 21200 | 11300 | |
| | Loss | | | 453 | | | 157 | | | 3833 | 6608 |
| 21 | Check | 1830 | 1830 | 0 | 590 | 590 | 0 | 21200 | 21200 | 0 | |
| 22 | CaO | 1760 | 1852 | −92 | 520 | 593 | −73 | 19400 | 21317 | −1917 | |
| | Loss | | | 92 | | | 73 | | | 1917 | 3235 |

*See Table VIII.

One reason for this may be the fact that an excess of lime was applied as compared to the needs of the soil although in no case did the application exceed 5500 pounds per acre in 15 years, which would not be considered excessively heavy. The lime requirement of the check plots at present amounts to practically 3000 pounds of $CaCO_3$ per 2,000,000 pounds of surface soil, which is equivalent to 1680 pounds of CaO. It will be seen, therefore, that lime was applied in considerably larger amounts than the surface soil required. However, the subsoils on the plots receiving lime still show a lime requirement averaging over 3200 pounds of $CaCO_3$ to a depth of twenty inches.

## THE EFFECT OF MANURE AND FERTILIZERS ON THE LIME REQUIREMENT OF THE SOIL.

The use of manure and fertilizers has had a tendency to decrease the acidity of the soil as shown in Table XIII. Sulphate of potash is the only one of the three commercial fertilizers used which did not have this tendency.

The statement is frequently made that the use of acid phosphate will make a soil acid. This work verifies the statements published by certain other experiment stations*† and indicates that the belief that the soil will become acid from the use of acid phosphate is without foundation. The analyses of the plots together with the data showing their present crop producing power indicate that it is possible to grow very large crops on acid soils without the use of lime and at the same time to be able to bring about a gradual decrease in the lime requirement of these soils.

*Connor, S. D., Jour. Ind. & Eng. Chem., Vol. VIII, No. 1, p. 35.
†Brooks, Wm. P., Bulletin 162, Massachusetts Agricultural Experiment Station

TABLE XIII.—The Lime Requirement of the Soil of the Fertilizer Plots.
(Pounds of $CaCO_3$ Required per Acre.)

| Plot No. | Treatment | From 0 to 6⅔ Inches | | | From 6⅔ to 20 Inches | | | $CaCO_3$ Requirement Balance to 20 Inches |
|---|---|---|---|---|---|---|---|---|
| | | $CaCO_3$ Requirement | $CaCO_3$ Requirement Calculated from Checks | Gain or Loss | $CaCO_3$ Requirement | $CaCO_3$ Requirement Calculated from Checks | Gain or Loss | |
| 19 | N, P, K, CaO | — 920 | 2800 | —3720 | 1800 | 3200 | —1400 | —5160 |
| 20 | M, CaO | —1160 | 2800 | —3960 | 1400 | 3000 | —1600 | —5560 |
| 22 | CaO | —1600 | 2967 | —4567 | 1800 | 2767 | — 967 | —5534 |
| 23 | M(ash), N | 2800 | 3133 | — 333 | 3000 | 2733 | + 267 | — 66 |
| 25 | M | 2800 | 3467 | — 667 | 1600 | 2667 | —1067 | —1634 |
| 26 | N, P, K | 3200 | 3633 | — 433 | 2200 | 2633 | — 433 | — 866 |
| 28 | P, K | 3600 | 3800 | — 200 | 2600 | 2667 | — 67 | — 267 |
| 29 | N, K | 3400 | 3800 | — 400 | 2600 | 2732 | — 132 | — 532 |
| 31 | N, P | 3200 | 3733 | — 533 | 2600 | 2732 | — 132 | — 665 |
| 32 | K | 3600 | 3667 | — 67 | 2800 | 2667 | + 133 | + 66 |
| 34 | P | 3400 | 3600 | — 200 | 2600 | 2600 | — 0 | — 200 |
| 35 | N | 3400 | 3600 | — 200 | 2600 | 2600 | — 0 | — 200 |

## THE APPLICATION OF THESE INTERPRETATIONS.

The analyses of these plots and the interpretations put on them, if they are correct, indicate several things of far-reaching importance to the agriculture of West Virginia:

1. The nitrogen of the soil can be maintained and increased without purchasing it in the form of commercial fertilizers, even if all the crops are removed from the farm. In fact it does not seem at all necessary, in view of the results obtained on the Experiment Station farm as to crop yields and also as to the present nitrogen content of the soil on the plots receiving phosphorus and potassium, to buy nitrogen in the form of fertilizers for permanent soil building.

2. The value of phosphorus and potassium over phosphorus alone as a fertilizer may, at least partly if not largely, be explained by an indirect function of potassium: viz., its value as an aid to nitrogen fixation. It seems possible from these analyses that it may be advisable to include potassium in the fertilizer used on soils in a low state of fertility instead of using acid phosphate alone as is now being largely practiced in West Virginia. This does not mean that the use of acid phosphate alone is objectionable but that a combination of potash salts and acid phosphate may be more effective not alone in its present crop-producing power but also in its residual effect on the soil. However, this potash supply may be manure instead of fertilizer.

3. Soil acidity is not necessarily a condition of the soil which must be overcome by the use of lime in order to produce satisfactory crops. The soil on the Experiment Station farm has a higher lime requirement than the average West Virginia soil. Yet, excellent crops have been produced at a profit on the Experiment Station farm without the use of either lime or limestone. The plots receiving acid phosphate, acid phosphate and sulphate of potash, complete fertilizer, and manure are in much better condition today than they were when the experiment was begun in 1900. These plots not only show a lower acidity than the check plots but they have a much higher content of both organic matter and nitrogen than they had originally.

This would indicate that farmers living some distance from a railroad station or from a source of lime or limestone are not compelled to buy and apply lime in order to produce

large crops economically. This does not mean, however, that limestone, where it can be secured at a reasonable cost, can not be applied to advantage on acid soils.

4. These analyses indicate that organic matter can be maintained and increased in the soil without plowing down anything but the stubble left behind after the crops have been harvested, if a rotation of crops is followed and use is made of either fertilizer or manure. Organic matter can be increased in the soil by growing large crops in rotation, even though the crops are removed from the farm. It has always seemed doubtful in the minds of writers whether the spasmodic attempts to increase the organic matter in the soil by plowing down some crop such as soybeans, which could have been used for some other purpose, is advisable. Such a procedure not only means the loss of the use of the land for that season but also a considerable cost for labor and seed. The soybeans could have been fed as hay and the manure returned to the field, or they could have been sold and a part of their value invested in fertilizer. Either the fertilizer or the manure, by reason of the fact that it produced a large crop, would have increased the organic matter in the soil by the roots and stubble of this crop.

This is not meant to discourage the plowing down of cover crops but is meant to imply that it does not seem advisable to lose the use of the soil during the main growing season for this purpose.

5. The evidence indicates that the acidity of the soil can be reduced by increasing the organic matter in the soil. The plots receiving manure show a reduced acidity. The plots which have received any combination of fertilizers which increased the yields materially show a higher content of organic matter and a lower acidity than neighboring check plots. In general it may be said that the acidity of the plots has been reduced wherever the content of organic matter has been increased. Limestone boulders which by accident were buried in an acid soil, when excavated a few years later, were covered with a heavy coating of very black organic matter such as to make them have the appearance of coal. It seems possible that the reverse of this may be true: viz., that if the soil is well stocked with organic matter, the lime in solution in the soil may be precipitated by this organic matter. On the subsequent decay of this organic matter the lime may be released as the carbonate. We consider this statement merely as a working hypothesis.

6. The best means of maintaining the fertility of the soil is to make it produce large crops. If for any reason the yield begins to gradually decrease, the result will be that the nitrogen and organic matter will begin to decrease and the acidity of the soil will increase. When once the soil has reached the state of unproductivity in which many West Virginia soils are found today heroic efforts may be required to bring them back to a normal state of productivity. We feel quite sure, however, that these worn out soils can be made to produce large crops by making use of nothing but acid phosphate in connection with good farming. We believe it can be done more rapidly and perhaps more economically by the use of potash and lime. Again it can be hastened by the use of nitrogenous fertilizers, but we are inclined to believe that this is doubtful economy.

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West Virginia University
Agricultural Experiment Station
MORGANTOWN

DEPARTMENT OF SOILS

# ANALYSES OF ONE HUNDRED WEST VIRGINIA SOILS

BY
Firman E. Bear and Robert M. Salter

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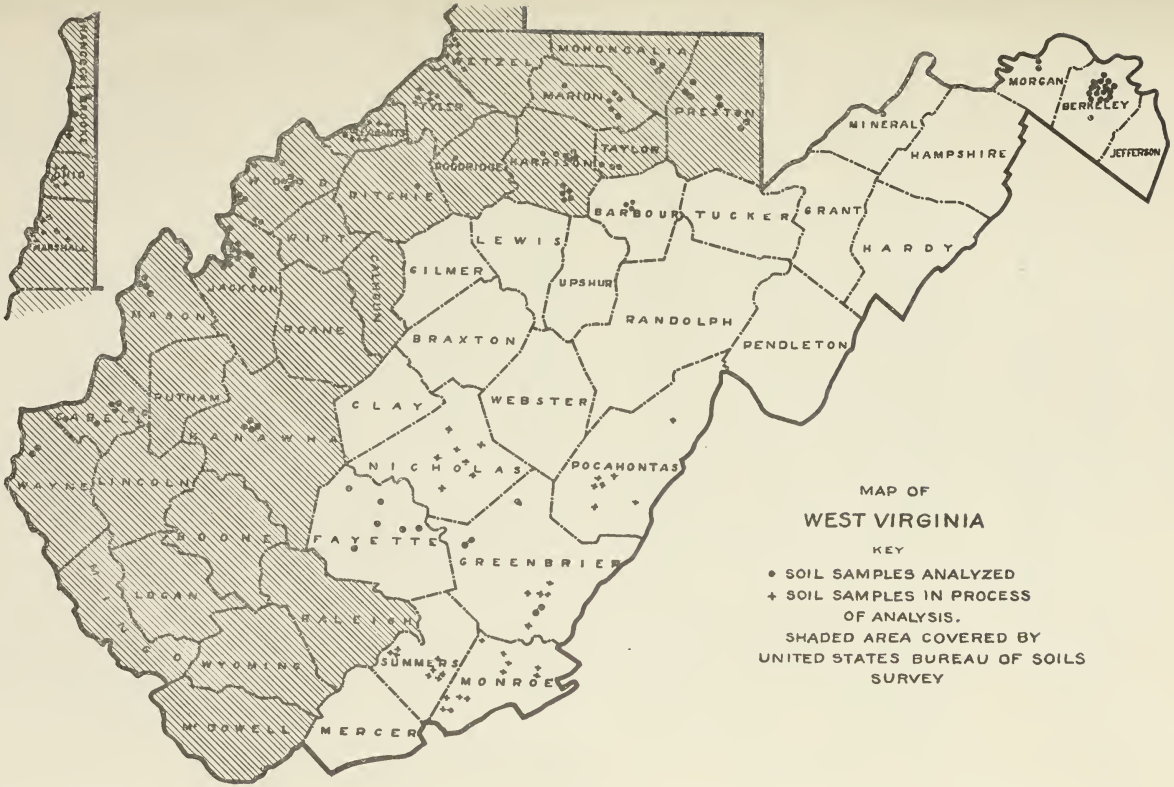


MAP OF

WEST VIRGINIA

KEY

• SOIL SAMPLES ANALYZED

+ SOIL SAMPLES IN PROCESS OF ANALYSIS.

SHADED AREA COVERED BY UNITED STATES BUREAU OF SOILS SURVEY

## CONCLUSIONS.

**These conclusions are summarized from the analyses of one hundred samples of West Virginia soils.**

1. Fifty percent of these soils contain less than 1000 pounds of phosphorus per acre to a depth of 6⅔ inches. The use of acid phosphate on such soils would produce a marked increase in their crop-producing power.

2. Over forty percent of these soils contain less than 2500 pounds of nitrogen per acre to a depth of 6⅔ inches. Heavy yields of most crops cannot be produced on such soils until more nitrogen is present in them. This nitrogen can be secured from the air by growing legumes.

3. Ninety percent of these soils show a need of lime averaging over one ton of limestone per acre. Alfalfa and red clover cannot be grown to advantage on such soils until lime has been applied. Either ground limestone or burned lime can be used to advantage.

4. The amount of organic matter present in these soils is not half what it should be. The organic matter can be increased by growing larger crops and by plowing under cover crops and manure.

5. Eighty percent of these soils contain more than 20,000 pounds of potassium per acre to plow depth. If the other deficiencies in these soils were supplied, there should be sufficient available potassium to prevent its being a limiting factor.

# Analyses of One Hundred West Virginia Soils*

By FIRMAN E. BEAR and ROBERT M. SALTER.

It is the intention of the department of soils of the West Virginia Agricultural Experiment Station to make a study of the most important soil types in every county of the state and to determine the amounts of the various plant food elements contained in them. This bulletin is a preliminary report concerning the most prominent soil series together with the analyses of 100 samples chosen from certain sections of the state.

## SOIL SURVEYS OF THE UNITED STATES BUREAU OF SOILS.

The United States Bureau of Soils has been co-operating with the West Virginia Geological Survey in its work in this state. As each area is surveyed as to its mineral content it is also mapped as to its soil types. It has seemed advisable to accept the soil classification as outlined by the Bureau of Soils and to choose our samples as largely as possible from areas which have already been surveyed. Up to the present time one-half of the state has been mapped. The soil surveys are issued under authorization of Congress and the distribution provides 500 copies of each soil survey in the state for each of the senators from the state and 2000 copies of each survey for the congressman representing the district in which the survey is located. Soil surveys are available for the following counties and can be obtained by writing to the senators or to the congressmen representing the various districts:

| | | | |
|---|---|---|---|
| Boone | Kanawha | Monongalia | Taylor |
| Brooke | Lincoln | Ohio | Tyler |
| Cabell | Logan | Pleasants | Upshur |
| Calhoun | McDowell | Preston | Wayne |
| Doddridge | Marion | Putnam | Wetzel |
| Hancock | Marshall | Raleigh | Wirt |
| Harrison | Mason | Ritchie | Wood |
| Jackson | Mingo | Roane | Wyoming |

*For methods of analysis see Bulletin 159, West Virginia Agricultural Experiment Station, Morgantown.

Many of the soils, the analyses of which are given in this bulletin, have been chosen from the above named counties and represent definite soil types. Other samples have been chosen from areas which have not yet been surveyed and represent definite soil types which will be classified later when the soil survey of the state has been completed.

The Bureau of Soils* has divided the United States into 13 soil provinces or regions. "A province is an area in which the soils have been produced by the same force or group of forces."

In West Virginia three provinces are represented:

I. Limestone Valleys and Uplands Province.

II. Appalachian Mountains and Plateaus Province.

III. The River Flood Plains Province.

In each province there are several soil series. "A soil series is a group of soils having the same range in color, the same character of subsoil as regards color and structure, the same relief and drainage and a common or similar origin."

The following series are represented in West Virginia in the areas so far surveyed. This does not include the Eastern Panhandle or the soils of the types in Greenbrier and Pocahontas counties.

I. Limestone Valleys and Uplands Province

1. Brooke series
   a. Soils grayish brown to brown.
   b. Subsoils yellowish brown to reddish brown clay.
   c. Soils derived from pure limestone with an occasional admixture of material from sandstone and shales.
   d. Soils with good drainage, fairly productive, easy to cultivate.

2. Hagerstown series (Not surveyed as yet in West Virginia but present in limestone valley section of Greenbrier and Pocahontas and other eastern counties and in the Eastern Panhandle).
   a. Soils prevailing brown in color.
   b. Subsoils light brown to reddish brown.
   c. Soils derived from pure massive limestone.
   d. Soils very productive and suitable for most crops

II. Appalachian Mountains and Plateaus Province

1. Dekalb series
   a. Soils gray to brown.
   b. Subsoils some shade of yellow.

*U. S. Bureau of Soils, Bulletin 96.

c. Soils derived from sandstone and shales.
d. Soils generally not very productive. (West Virginia Experiment Station farm is Dekalb soil.)

2. Meigs series
a. Soils variable in character from gray or pale yellow to red.
b. Subsoils variable.
c. Soils a mixture of Dekalb and Upshur.
d. Soils on hilly areas difficult to cultivate.

3. Upshur series
a. Soils Indian red.
b. Subsoils Indian red.
c. Derived from sandstone and shales, frequently calcareous in nature.
d. Generally fairly productive.

4. Westmoreland series
a. Soils grayish brown to yellowish brown.
b. Subsoils yellowish to yellowish brown.
c. Derived from sandstone and shales with interbedded limestone and calcareous shales.
d. Soils very productive.

III. The River Flood Plains Province

A. Terrace Soils

1. Elk series
a. Soils light brown to brown.
b. Yellow subsoils.
c. Soils contain limestone, alluvium from Westmoreland series.
d. Soils fairly productive.

2. Holston series
a. Soils yellowish brown to brown.
b. Subsoils yellow.
c. Soils from sandstone and shale.
d. Only fairly productive.

3. Tyler series
a. Soils gray to grayish brown.
b. Subsoils yellowish to mottled yellow and gray.
c. Soils largely from sandstone and shale, poorly drained.
d. Not very productive.

4. Wheeling series
a. Soils brown to yellowish brown.
b. Subsoils gravelly.
c. Soils from glacial material.
d. Very productive.

B. First Bottom Soils

5. Holly series
   a. Soils gray.
   b. Subsoils mottled gray and yellow.
   c. Contain some limestone, poorly drained.
   d. Not very productive.

6. Huntington series.
   a. Soils light brown to brown.
   b. Subsoils yellow to light brown.
   c. Contain some limestone.
   d. Very productive.

7. Moshannon series
   a. Soils reddish brown to Indian red.
   b. Subsoils reddish brown.
   c. Soils from alluvium from Upshur series.
   d. Very productive.

Table 1 shows the number of acres belonging to each series in the area so far surveyed.

**TABLE I.—Acres of Land in Various Soil Series in West Virginia.**

| Series | Acres |
|---|---|
| Dekalb | 3,142,536 |
| Meigs | 2,718,848 |
| Rough Stony Land | 823,466 |
| Huntington | 360,576 |
| Upshur | 319,744 |
| Westmoreland | 166,080 |
| Holston | 120,512 |
| Moshannon | 62,592 |
| Tyler | 60,672 |
| Brooke | 47,232 |
| Wheeling | 40,770 |
| Elk | 31,872 |
| Holly | 27,520 |
| Miscellaneous | 12,928 |
| Total | 7,935,348 |

In each of these soil series there are several soil types. "A soil type is a soil which throughout the area of its occurrence has the same texture, structure, color, character of subsoil, general topography, process of derivation, and usually derived from the same material." There may, therefore, be sands, silts, loams, and clays in each of the above series. For example, the soil on the West Virginia Agricultural Experiment Station farm is a Dekalb silt loam.

## TABLE II†.—Pounds per 2,000,000 Lbs. of Surface Soil*.

| Sample Number | Owner of Farm | Postoffice | Soil Series | Nitrogen | Phosphorus | Potassium | Carbon | Limestone Requirem't |
|---|---|---|---|---|---|---|---|---|
| **Barbour County** | | | | | | | | |
| 85-A | W. D. Zinn | Philippi | Tyler | 3214 | 835 | 18600 | 35510 | 1800 |
| 90-A | W. D. Zinn | Philippi | ? | 4185 | 1236 | 27400 | 43910 | 3200 |
| 112-A | W. D. Zinn | Philippi | Upshur | 4102 | 1236 | 49600 | 32210 | 1600 |
| **Berkeley County** | | | | | | | | |
| 24-A | John Miller | Martinsburg | Hagerstown(?) | 2358 | 1631 | 40600 | 19620 | 1000 |
| 25-A | John Miller | Martinsburg | ? | 2433 | 1420 | 51400 | 29120 | 1800 |
| 26-A | Back Creek Or. Co. | Hedgesville | Hagerstown(?) | 1442 | 536 | 23800 | 22010 | 2400 |
| 27-A | Gray Silver | Martinsburg | ? | 2515 | 1150 | 40200 | 24960 | 1400 |
| 28-A | John Miller | Martinsburg | Hagerstown | 2081 | 2020 | 53800 | 15480 | 800 |
| 29-A | Mrs. Lupton | Martinsburg | Hagerstown | 2235 | 1086 | 49000 | 23030 | 0 |
| 30-A | Mr. Aler | Martinsburg | Soapstone | 2478 | 1398 | 39200 | 24960 | 1800 |
| 31-A | A. R. Feltner | Martinsburg | Soapstone & Clay | 1705 | 752 | 21600 | 20310 | 200 |
| 32-A | J. W. Stewart | Tabler | Hagerstown | 2152 | 1282 | 49600 | 21660 | 0 |
| 33-A | D. Gold Miller | Martinsburg | Hagerstown(?) | 2296 | 917 | 108800 | 23950 | 1000 |
| 34-A | Dr. Shipper | Gerrardstown | Hagerstown(?) | 2558 | 1322 | 31200 | 26110 | 3000 |
| 35-A | Geo. Shroades | Gerrardstown | ? | 2602 | 1364 | 39000 | 18150 | 2400 |
| 36-A | H. L. Smith | Arden | ? | 2932 | 1035 | 143000 | 31720 | 1800 |
| 37-A | Gr. Golden Or. Co. | Martinsburg | Hagerstown(?) | 2486 | 1327 | 55000 | 27290 | 2200 |
| 38-A | Senator Silver | Gerrardstown | Hagerstown(?) | 3083 | 1117 | 52600 | 30480 | 0 |
| **Brooke County** | | | | | | | | |
| 40-A | Robt. Underwood | Wellsburg | Huntington | 5912 | 2648 | 38000 | 67010 | 3000 |
| 42-A | Robt. Patterson | Wellsburg | Brooke | 3646 | 1365 | 48000 | 53010 | 0 |
| 111-A | ..... | Follansbee | Wheeling | 1940 | 1550 | 21600 | ..... | 3600 |
| 114-A | Wm. Brady | Collier | Brooke(?) | 3060 | 1125 | 31200 | 30970 | 2800 |
| **Cabell County** | | | | | | | | |
| 4-A | Mr. Wilson | Ona | Meigs | 1375 | 588 | 26800 | 19170 | 4400 |

†Credit is due E. B. Wells and M. F. Morgan for assistance in making these analyses.
*This represents the amount of soil in a layer over an acre to a depth of 6⅔ inches.

TABLE II (Continued).—Pounds per 2,000,000 Lbs. of Surface Soil.

| Sample Number | Owner of Farm | Postoffice | Soil Series | Nitrogen | Phosphorus | Potassium | Carbon | Limestone Requirem't |
|---|---|---|---|---|---|---|---|---|
| **Cabell County (Cont'd)** | | | | | | | | |
| 18-A | Mr. Clark | Ona | Upshur | 2482 | 1218 | 49800 | 21620 | 0 |
| 21-A | Mr. Sios | Ona | Holston | 1537 | 830 | 17600 | 15210 | 1400 |
| 22-A | C. R. Morris | Martha | Holston(?) | 2893 | 2066 | 56600 | 31760 | 1800 |
| 74-A | Perry Lawson | Milton | Dekalb | 1520 | 370 | 17200 | 21210 | 1000 |
| 75-A | J. H. Moore | Milton | Holston(?) | 4344 | 1187 | 35400 | 62970 | 0 |
| 79-A | Ed. Kyle | Coxs Landing | Wheeling | 1824 | 892 | 25600 | 17810 | 2000 |
| 84-A | John White | Culloden | Holston | 1764 | 566 | 14400 | 20230 | 2200 |
| **Doddridge County** | | | | | | | | |
| 113-A | J. E. Coleman | West Union | Holston(?) | 3240 | 806 | 27800 | 34770 | 1800 |
| **Fayette County** | | | | | | | | |
| 39-A | B. A. Fleshman | Fayetteville | Dekalb | 1210 | 421 | 11000 | 25370 | 2200 |
| 58-A | L. V. Shawver | Corliss | Dekalb | 3124 | 753 | 18400 | 48280 | 4600 |
| 61-A | T. C. Jones | Oak Hill | Dekalb | 2082 | 483 | 16000 | 30550 | 2400 |
| 65-A | L. P. Wills | Mt. Cove | Dekalb | 2602 | 662 | 11200 | 32450 | 2200 |
| 109-A | J. B. Kesler | Clifty | Dekalb | 3384 | 660 | 20200 | 39490 | 2800 |
| **Greenbrier County** | | | | | | | | |
| 44-A | L. E. McClung | Rupert | ? | 3116 | 1590 | 22000 | 54270 | 6800 |
| 45-A | J. O. McClung | Rupert | ? | 3680 | 708 | 17000 | 65800 | 4000 |
| 46-A | David Tuckwiller | Lewisburg | Soapstone | 2824 | 1160 | 13800 | 28550 | 2600 |
| 47-A | Rev. H. A. Murrill | Lewisburg | Hagerstown(?) | 2884 | 1289 | 27400 | 26560 | 1200 |
| **Harrison County** | | | | | | | | |
| 1-A | Fred Whitman | Adamston | Westmoreland | 2930 | 1226 | 42400 | 31330 | 2800 |
| 87-A | Arthur Sheets | Lost Creek | Dekalb | 2750 | 706 | 22000 | 32140 | 3200 |
| 88-A | L. D. Blake | Lost Creek | Huntington | 4324 | 1242 | 25000 | ..... | 1800 |
| 91-A | A. H. Davidson | Lost Creek | Dekalb | 4906 | 1219 | 22200 | 53090 | 1800 |
| 92-A | A. H. Davidson | Lost Creek | Dekalb | 3142 | 902 | 25800 | 32140 | 1600 |
| 98-A | Arthur Sheets | Lost Creek | Elk | 2534 | 706 | 17800 | 25690 | 2000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 100-A | Jackson Arnold | Lost Creek | Huntington | 5822 | 1362 | 27400 | 62360 | 3600 |
| 101-A | A. J. Lodge | ..... | ? | 6406 | 1858 | 32200 | 70130 | 2200 |
| 103-A | A. A. Long & Bro. | Bridgeport | Huntington | 5046 | 1553 | 28000 | 48450 | 1200 |
| 104-A | S. S. Farris | Bridgeport | Dekalb | 3046 | 784 | 22600 | 29180 | 2200 |
| 106-A | R. E. L. Stout | Bridgeport | Elk | 3274 | 1376 | 23800 | 29630 | 200 |
| **Jackson County** | | | | | | | | |
| 48-A | Mr. Bradbury | Sherman | ? | 2330 | 1226 | 32400 | 29020 | 5600 |
| 49-A | W. C. Statts | Sherman | Huntington | 2016 | 864 | 19000 | 54990 | 0 |
| 50-A | W. C. Statts | Sherman | Huntington | 1995 | 1091 | 24200 | 36360 | 0 |
| 51-A | Virgil Bower | Crow Summit | Moshannon | 2152 | 1034 | 21600 | 22640 | 2400 |
| 52-A | Ruben Pickens | Ravenswood | Dekalb | 2042 | 1216 | 26600 | 20280 | 2000 |
| 53-A | F. A. Morgan | Ravenswood | Moshannon | 1670 | 874 | 25000 | 16580 | 2600 |
| 54-A | F. A. Morgan | Ravenswood | Moshannon | 2144 | 973 | 24200 | 23860 | 1400 |
| 55-A | Isaac Starkey | Ravenswood | Holston | 2164 | 739 | 19400 | 22970 | 0 |
| 56-A | M. F. Morgan | Ravenswood | Upshur | 1755 | 546 | 20800 | 21090 | 2600 |
| 57-A | M. F. Morgan | Ravenswood | Holston | 1035 | 354 | 21400 | 16730 | 2800 |
| 83-A | W. A. Proctor | Ravenswood | Wheeling | 3784 | 3636 | 23400 | 45810 | 0 |
| 102-A | Chas. Kalt | Crow Summit | Moshannon | 2430 | 862 | 24800 | 16180 | 1800 |
| **Jefferson County** | | | | | | | | |
| 5-A | C. D. Wysong | Shepherdstown | Hagerstown | 2336 | 1218 | 51000 | 27150 | 0 |
| **Kanawha County** | | | | | | | | |
| 43-A | E. C. Crane | Poca | Holston(?) | 3322 | 1529 | 37200 | 31850 | 3200 |
| 107-A | Lewis Milam | Charleston | Dekalb | 2610 | 653 | 25800 | 28780 | 2000 |
| 108-A | W. A. Lawson | Charleston | Dekalb | 2224 | 434 | 16600 | 30580 | 1600 |
| 110-A | Geo. Johnson | Charleston | Holston | 1890 | 715 | 10100 | 18020 | 2000 |
| **Marion County** | | | | | | | | |
| 81-A | County Poor Farm | Fairmont | Westmoreland | 2746 | 1020 | 35600 | ..... | 2400 |
| 86-A | Mr. Meredith | Fairmont | Huntington(?) | 3846 | 1119 | 27400 | 41380 | 3800 |
| 89-A | J. S. Nuzum | Colfax | Westmoreland | 4076 | 1526 | 34800 | ..... | 2000 |
| 95-A | J. F. Phillips | Fairmont | Elk | 3280 | 997 | 23000 | 36220 | 0 |
| 96-A | L. N. Beatty | Mannington | Moshannon | 3444 | 1226 | 32600 | 30470 | 3800 |
| 99-A | W. F. Boyers | Fairmont | Elk | 2744 | 839 | 23200 | 26950 | 2000 |

TABLE II (Continued).—Pounds per 2,000,000 Lbs. of Surface Soil.

| Sample Number | Owner of Farm | Postoffice | Soil Series | Nitrogen | Phosphorus | Potassium | Carbon | Limestone Requirem't |
|---|---|---|---|---|---|---|---|---|
| **Mason County** | | | | | | | | |
| 76-A | J. T. Kincaid | Pt. Pleasant | Holston | 1615 | 649 | 22600 | 15490 | 1600 |
| 78-A | J. McCausland | Pt. Pleasant | Moshannon | 3316 | 712 | 39000 | 31700 | 5200 |
| 80-A | Ira Z. Swisher | Pt. Pleasant | Huntington | 2975 | 1557 | 22600 | 30050 | 2200 |
| 82-A | Jerome Plants | Ambrosia | Upshur | 1760 | 425 | 39000 | 20990 | 3800 |
| **Mineral County** | | | | | | | | |
| 20-A | Ed. Leatherman | Keyser | ? | 6485 | 776 | 7400 | 175630 | 3800 |
| **Monongalia County** | | | | | | | | |
| 2-A | Exp. Station | Morgantown | Dekalb | ..... | 698 | 28400 | 22900 | 3000 |
| 16-A | Exp. Station | Morgantown | Dekalb | 2058 | 718 | 26000 | 23140 | 3000 |
| 23-A | Geo. C. Sturgiss | Morgantown | ? | 6821 | 1630 | 30800 | 77210 | 2000 |
| **Morgan County** | | | | | | | | |
| 10-A | Mr. Henry | Stotlers Cross Roads | Clay Loam | 2272 | 891 | 18000 | 29000 | 2400 |
| 11-A | Mr. Henry | Stotlers Cross Roads | Silt Loam | 3517 | 626 | 19000 | 16690 | 800 |
| 17-A | Somer's Orchard | Cherry Run | ? | 2331 | 798 | 30200 | 38080 | 4000 |
| 19-A | Somer's Orchard | Cherry Run | ? | 2357 | 925 | 29600 | 31400 | 1200 |
| **Nicholas County** | | | | | | | | |
| 41-A | E. P. Foster | Gauley Bridge | Black Sand | 2135 | ..... | 1200 | 38630 | 5000 |
| **Pleasants County** | | | | | | | | |
| 6-A | J. B. Kester | Belmo t | Wheeling | 3423 | 2248 | 23000 | 38460 | 3000 |
| **Preston County** | | | | | | | | |
| 66-A | A. M. McMillen | Masontown | Dekalb | 3374 | 697 | 20000 | 47230 | 1400 |
| 67-A | Sanford Watson | Masontown | Dekalb | 4326 | 2159 | 26000 | 47320 | 1600 |
| 68-A | B. T. Gibson | Masontown | Holly | 3984 | 923 | 24600 | 45700 | 1600 |
| 69-A | J. F. Copeman | Kingwood | Dekalb(?) | 4746 | 2146 | 31000 | 49230 | 1400 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 70-A | County Farm | Kingwood | Dekalb | 3870 | 1203 | 27000 | 41420 | 400 |
| 71-A | T. B. Taylor | Terra Alta | Upshur | 2986 | 761 | 25600 | 37250 | 0 |
| 72-A | J. A. Dodge | Terra Alta | Dekalb | 4142 | 1135 | 23400 | 48680 | 2600 |
| **Ritchie County** | | | | | | | | |
| 60-A | J. F. Lowther | Pullman | Upshur | 2802 | ..... | 34800 | 26820 | 5000 |
| **Roane County** | | | | | | | | |
| 97-A | C. C. Hardman | Spencer | Dekalb | 2132 | 482 | 27400 | 22880 | 2200 |
| **Taylor County** | | | | | | | | |
| 3-A | G. Smith | Flemington | ? | 4268 | 1603 | 32400 | 57590 | 2400 |
| 14-A | F. B. Haller | Rosemont | Westmoreland | 2954 | 1181 | 25000 | 34360 | 3000 |
| 15-A | M. G. Lawson | Flemington | Elk | 3699 | 1213 | 22000 | 40400 | 3400 |
| **Wayne County** | | | | | | | | |
| 12-A | W. J. Smith | Centerville | Holston | 2299 | 806 | 21200 | 26170 | 1200 |
| 13-A | W. F. Plymale | Centerville | Holston | 3385 | 1148 | 33600 | 34280 | 3400 |
| **Wood County** | | | | | | | | |
| 7-A | Mr. Creel | Davisville | Tyler | 2680 | 1163 | 25200 | 27450 | 3400 |
| 8-A | J. A. Creel | Davisville | Upshur | 2551 | 950 | 37600 | 25900 | 5200 |
| 9-A | J. A. Creel | Davisville | Dekalb | 1669 | 680 | 26200 | 17601 | 1200 |
| 59-A | J. F. Doan | Parkersburg | Upshur | 2077 | ..... | 36400 | 18350 | 6400 |
| 62-A | J. W. Miller | Mineral Wells | Huntington | 1550 | 782 | 18400 | 14150 | 800 |
| 63-A | E. J. Humphrey | Belleville | Huntington | 2724 | 1457 | 14200 | 33680 | 800 |
| 64-A | A. F. Bonar | Belleville | Brooke | 3004 | 1543 | 40200 | 30120 | 0 |
| 73-A | H. G. Butcher | Mineral Wells | Huntington | 1970 | 918 | 34200 | 16490 | 2400 |
| 77-A | Mr. Barnett | Davisville | Tyler | 3910 | 1108 | 34800 | 41380 | 5200 |
| 93-A | S. F. Romine | Washington | Dekalb | 1904 | 586 | 22200 | 21790 | 1000 |
| 94-A | Dr. Keefer | Belleville | Wheeling | 3496 | 1563 | 26200 | 31480 | 1400 |
| **Wayne County, Ohio** | | | | | | | | |
| 115-A | Ohio Exp. Sta. | Wooster, Ohio | Volusia | 1775 | 664 | 28600 | ..... | 3200 |

TABLE III.—Pounds per 2,000,000 Lbs. of Surface Soil.

| Sample Number | Owner of Farm | Postoffice | County | Nitrogen | Phosphorus | Potassium | Carbon | Limestone Requirem't |
|---|---|---|---|---|---|---|---|---|
| **Brooke Series** | | | | | | | | |
| 42-A | Robt. Patterson | Wellsburg | Brooke | 3646 | 1365 | 48000 | 53010 | 0 |
| 64-A | A. F. Bonar | Belleville | Wood | 3004 | 1543 | 40200 | 30120 | 0 |
| 114-A? | Wm. Brady | Collier | Brooke | 3060 | 1125 | 31200 | 30970 | 2800 |
| **Dekalb Series** | | | | | | | | |
| 2-A | Exp. Station | Morgantown | Monongalia | ..... | 698 | 28400 | 22900 | 3000 |
| 9-A | J. A. Creel | Davisville | Wood | 1669 | 680 | 26200 | 17601 | 1200 |
| 10-A | Mr. Henry | Stotlers Cross Roads | Morgan | 2272 | 891 | 18000 | 29000 | 2400 |
| 16-A | Exp. Station | Morgantown | Monongalia | 2058 | 718 | 26000 | 23140 | 3000 |
| 39-A | B. A. Fleshman | Fayetteville | Fayette | 1210 | 421 | 11000 | 25370 | 2200 |
| 52-A | Ruben Pickens | Ravenswood | Jackson | 2042 | 1216 | 26600 | 20280 | 2000 |
| 58-A | L. V. Shawver | Corliss | Fayette | 3124 | 753 | 18400 | 48280 | 4600 |
| 61-A | T. C. Jones | Oak Hill | Fayette | 2082 | 483 | 16000 | 30550 | 2400 |
| 65-A | L. P. Wills | Mountain Cove | Fayette | 2602 | 662 | 11200 | 32450 | 2200 |
| 66-A | A. F. McMillen | Masontown | Preston | 3374 | 697 | 20000 | 47230 | 1400 |
| 67-A? | Sanford Watson | Masontown | Preston | 4326 | 2159 | 26000 | 47320 | 1600 |
| 69-A? | J. F. Copeman | Kingwood | Preston | 4746 | 2146 | 31000 | 49230 | 1400 |
| 70-A | County Farm | Kingwood | Preston | 3870 | 1203 | 27000 | 41420 | 400 |
| 72-A | J. A. Dodge | Terra Alta | Preston | 4142 | 1135 | 23400 | 48680 | 2600 |
| 74-A | Perry Lawson | Milton | Cabell | 1520 | 370 | 17200 | 21210 | 1000 |
| 87-A | Arthur Sheets | Lost Creek | Harrison | 2750 | 706 | 22000 | 32140 | 3200 |
| 90-A | W. D. Zinn | Philippi | Barbour | 4185 | 1236 | 27400 | 43910 | 3200 |
| 91-A | A. H. Davidson | Lost Creek | Harrison | 4906 | 1219 | 22200 | 53090 | 1800 |
| 92-A | A. H. Davidson | Lost Creek | Harrison | 3142 | 902 | 25800 | 32140 | 1600 |
| 93-A | S. F. Romine | Washington | Wood | 1904 | 586 | 22200 | 21790 | 1000 |
| 97-A | C. C. Hardman | Spencer | Roane | 2132 | 482 | 23800 | 22880 | 2200 |
| 104-A | S. S. Farris | Bridgeport | Harrison | 3046 | 784 | 22600 | 29180 | 2200 |
| 107-A | Lewis Milam | Charleston | Kanawha | 2610 | 653 | 25800 | 28780 | 2000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 108-A | W. A. Lawson | Charleston | Kanawha | 2224 | 434 | 16600 | 30580 | 1600 |
| 109-A | J. B. Kessler | Clifty | Fayette | 3384 | 660 | 20200 | 39490 | 2800 |
| **Elk Series** | | | | | | | | |
| 15-A | M. G. Lawson | Flemington | Taylor | 3699 | 1213 | 22000 | 40400 | 3400 |
| 95-A | J. F. Phillips | Fairmont | Marion | 3280 | 997 | 23000 | 36220 | 0 |
| 98-A | Arthur Sheets | Lost Creek | Harrison | 2534 | 706 | 17800 | 25690 | 2000 |
| 99-A | W. F. Boyers | Fairmont | Marion | 2744 | 839 | 23200 | 26950 | 2000 |
| 106-A | R. E. L. Stout | Bridgeport | Harrison | 3274 | 1376 | 23800 | 29630 | 200 |
| **Hagerstown Series** | | | | | | | | |
| 5-A | C. D. Wysong | Shepherdstown | Jefferson | 2336 | 1218 | 51000 | 27150 | 0 |
| 24-A? | John Miller | Martinsburg | Berkeley | 2358 | 1631 | 40600 | 19620 | 1000 |
| 26-A? | Back Creek Or. Co. | Hedgesville | Berkeley | 1442 | 536 | 23800 | 22010 | 2400 |
| 28-A | John Miller | Martinsburg | Berkeley | 2081 | 2020 | 53800 | 15480 | 800 |
| 29-A | Mrs. Lupton | Martinsburg | Berkeley | 2235 | 1086 | 49000 | 23030 | 0 |
| 32-A | J. W. Stewart | Tabler | Berkeley | 2152 | 1282 | 49600 | 21660 | 0 |
| 33-A? | D. Gold Miller | Martinsburg | Berkeley | 2296 | 917 | 108800 | 23950 | 1000 |
| 34-A? | Dr. Shipper | Gerrardstown | Berkeley | 2558 | 1322 | 31200 | 26110 | 3000 |
| 37-A? | Gr. Golden Or. Co. | Martinsburg | Berkeley | 2486 | 1327 | 55000 | 27290 | 2200 |
| 38-A? | Senator Silver | Gerrardstown | Berkeley | 3083 | 1117 | 52600 | 30480 | 0 |
| 47-A | Rev. H. A. Murrill | Lewisburg | Greenbrier | 2884 | 1289 | 27400 | 26560 | 1200 |
| **Holston Series** | | | | | | | | |
| 12-A | W. J. Smith | Centerville | Wayne | 2299 | 806 | 21200 | 26170 | 1200 |
| 13-A | W. F. Plymale | Centerville | Wayne | 3385 | 1148 | 33600 | 34280 | 3400 |
| 21-A | Mr. Sios | Ona | Cabell | 1537 | 830 | 17600 | 15210 | 1400 |
| 22-A? | C. R. Morris | Martha | Cabell | 2893 | 2066 | 56600 | 31760 | 1800 |
| 43-A? | E. C. Crane | Poca | Kanawha | 3322 | 1529 | 37200 | 31850 | 3200 |
| 55-A | Isaac Starkey | Ravenswood | Jackson | 2164 | 739 | 19400 | 22970 | 0 |
| 57-A | M. F. Morgan | Ravenswood | Jackson | 1035 | 354 | 21400 | 16730 | 2800 |
| 75-A | J. H. Moore | Milton | Cabell | 4344 | 1187 | 35400 | 62970 | 0 |
| 76-A | J. T. Kincaid | Pt. Pleasant | Mason | 1615 | 649 | 22600 | 15490 | 1600 |
| 84-A | John White | Culloden | Cabell | 1764 | 566 | 14400 | 20230 | 2200 |

TABLE III (Continued).—Pounds per 2,000,000 Lbs. of Surface Soil.

| Sample Number | Owner of Farm | Postoffice | County | Nitrogen | Phosphorus | Potassium | Carbon | Limestone Requirem't |
|---|---|---|---|---|---|---|---|---|
| **Holston Series (Cont'd)** | | | | | | | | |
| 110-A | Geo. Johnson | Charleston | Kanawha | 1890 | 715 | 10100 | 18020 | 2000 |
| 113-A | J. E. Coleman | West Union | Doddridge | 3240 | 806 | 27800 | 34770 | 1800 |
| **Holly Series** | | | | | | | | |
| 68-A | B. T. Gibson | Masontown | Preston | 3984 | 923 | 24600 | 45700 | 1600 |
| **Huntington Series** | | | | | | | | |
| 40-A | Robt. Underwood | Wellsburg | Brooke | 5912 | 2648 | 38000 | 67010 | 3000 |
| 49-A | W. C. Statts | Sherman | Jackson | 2016 | 864 | 19000 | 54990 | 0 |
| 50-A | W. C. Statts | Sherman | Jackson | 1995 | 1091 | 24200 | 36360 | 0 |
| 62-A | J. W. Miller | Mineral Wells | Wood | 1550 | 782 | 18400 | 14150 | 800 |
| 63-A | E. J. Humphrey | Belleville | Wood | 2724 | 1457 | 14200 | 33680 | 800 |
| 73-A | H. G. Butcher | Mineral Wells | Wood | 1970 | 918 | 34200 | 16490 | 2400 |
| 80-A | Ira Z. Swisher | Pt. Pleasant | Mason | 2975 | 1557 | 22600 | 30050 | 2200 |
| 86-A | Mr. Meredith | Fairmont | Marion | 3846 | 1119 | 27400 | 41380 | 3800 |
| 88-A | L. D. Blake | Lost Creek | Harrison | 4324 | 1242 | 25000 | ..... | 1800 |
| 100-A | Jackson Arnold | Lost Creek | Harrison | 5822 | 1362 | 27400 | 62360 | 3600 |
| 103-A | A. A. Long & Bro. | Bridgeport | Harrison | 5046 | 1553 | 28000 | 48450 | 1200 |
| **Meigs Series** | | | | | | | | |
| 4-A | Mr. Wilson | Ona | Cabell | 1375 | 588 | ..... | 19170 | 4400 |
| **Moshannon Series** | | | | | | | | |
| 51-A | Virgil Bower | Crow Summit | Jackson | 2152 | 1034 | 21600 | 22640 | 2400 |
| 53-A | F. A. Morgan | Ravenswood | Jackson | 1670 | 874 | 25000 | 16580 | 2600 |
| 54-A | F. A. Morgan | Ravenswood | Jackson | 2144 | 973 | 24200 | 23860 | 1400 |
| 78-A | J. McCausland | Pt. Pleasant | Mason | 3316 | 712 | 39000 | 31700 | 5200 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 96-A | L. N. Beatty | Mannington | Marion | 3444 | 1226 | 32600 | 30470 | 3800 |
| 102-A | Chas. Kalt | Crow Summit | Jackson | 2439 | 862 | 24800 | 16180 | 1800 |
| **Tyler Series** | | | | | | | | |
| 7-A | Mr. Creel | Davisville | Wood | 2680 | 1163 | 25200 | 27450 | 3400 |
| 77-A | Mr. Barnett | Davisville | Wood | 2910 | 1108 | 34800 | 41380 | 5200 |
| 85-A? | W. D. Zinn | Philippi | Barbour | 3214 | 835 | 18600 | 35510 | 1800 |
| **Upshur Series** | | | | | | | | |
| 8-A | J. A. Creel | Davisville | Wood | 2551 | 950 | 37600 | 25900 | 5200 |
| 18-A | Mr. Clark | Ona | Cabell | 2482 | 1218 | 49800 | 21620 | 0 |
| 56-A | M. F. Morgan | Ravenswood | Jackson | 1755 | 546 | 20800 | 21090 | 2600 |
| 59-A | J. F. Dean | Parkersburg | Wood | 2077 | ..... | 36400 | 18350 | 6400 |
| 60-A | J. F. Lowther | Pullman | Ritchie | 2802 | ..... | 34800 | 26820 | 5000 |
| 71-A | T. B. Taylor | Terra Alta | Preston | 2986 | 761 | 25600 | 37250 | 0 |
| 82-A | Jerome Plants | Ambrosia | Mason | 1760 | 425 | 39000 | 20990 | 3800 |
| 112-A | W. D. Zinn | Philippi | Barbour | 4102 | 1236 | 49600 | 32210 | 1600 |
| **Westmoreland Series** | | | | | | | | |
| 1-A | Fred Whitman | Adamston | Harrison | 2930 | 1226 | 42400 | 31330 | 2800 |
| 14-A? | F. B. Haller | Rosemont | Taylor | 2954 | 1181 | 25000 | 34360 | 3000 |
| 81-A | Poor Farm | Fairmont | Marion | 2746 | 1020 | 35600 | ..... | 2400 |
| 89-A | J. S. Nuzum | Colfax | Marion | 4076 | 1526 | 34800 | ..... | 2000 |
| **Wheeling Series** | | | | | | | | |
| 6-A | J. B. Kester | Belmont | Pleasants | 3423 | 2248 | 23000 | 38460 | 3000 |
| 79-A | Ed. Kyle | Coxs Landing | Cabell | 1824 | 892 | 25600 | 17810 | 2000 |
| 83-A | W. A. Procter | Ravenswood | Jackson | 3784 | 3636 | 23500 | 45810 | 0 |
| 94-A | Dr. Keefer | Belleville | Wood | 3496 | 1563 | 26200 | 31480 | 1400 |
| 111-A | ..... | Follansbee | Brooke | 1940 | 1550 | 21600 | ..... | 3600 |

## HISTORY OF SOIL SAMPLES.

1-A—Discard*, 10.70%. Hillside noth of barn; cleared 40 to 50 years; soil, light gray; subsoil, yellowish; rolling highland; drainage, natural; bluegrass predominates in pasture; no manure applied, no fertilizer, no lime, no legumes grown; red clover does fairly well; sorrel is principal weed; soil varied more or less on side of hill and resulting sample was a composite representing several phases of this type of soil.

2-A.—No discard. (Plot 18) Soil, yellowish; level; taken from plot which has received no fertilizer or lime treatment for some time.

3-A.—Discard, 2.13%. Hickory, poplar, and sycamore originally grew on land; cleared approximately 75 years; soil, chocolate; subsoil, light brown; level overflow; drainage, natural; meadow since clearing, 2 tons per acre; timothy and orchard grass predominate; fed over in winter; no manure applied, no fertilizer, no lime; red clover with the grass; red clover apparently does well; yarrow, broad and narrow plantain, the principal weeds; limestone outcrops on hillside around flat.

4-A.—Discard, 7.15%. Top of hill back of barn; cleared one year; soil, light gray; subsoil, yellowish; rolling highland; drainage, natural; corn, 50 bushels per acre; no manure applied, no fertilizer, no lime; no legumes grown; do not know whether red clover does well or not; some sorrel. This represents new soil.

5-A.—Discard 3.17%. Between house and highway; white oak, hickory, walnut, and locust originally grew on land; cleared 100 years; soil, chocolate; subsoil, dark red; rolling highland; drainage, natural; corn each summer; rye each winter until this year (pasture); 38 bushels of corn per acre; 7 tons manure per acre each 3 years; 150 pounds of acid phosphate each year; 1 ton burned lime 12 years ago; hog weed, morning glory, Jamestown weed, the principal weeds; the field contains only about 1¼ acres but the rotation of corn and rye each year for thirty years makes it interesting. Field is just outside the corporation limits of Shepherdstown.

*The discard represents the particles of shale and rock which would not pass a 2-mm. sieve. This part was separated from the sample before analysis was made.

6-A.—Discard, 2.27%. Northeast of dwelling; beech, hickory, and sugar originally grew on land; cleared 75 years; soil, chocolate; subsoil, chocolate to yellow; level terrace; drainage, natural; meadow 9/10 of time; 2 tons of hay per acre; timothy and red top predominate; 12 tons manure applied once in 4 years; 300 pounds mixed goods applied 4 years ago; no lime; no legumes grown; very few red clover plants present; sedge, cinquefoil, and blue devil, the principal weeds; about fifteen acres level land in field about 100 yards northeast of railroad depot.

7-A.—Discard, 3.72%. Along road west of cross roads; cleared 75 years; soil, light gray; subsoil, darker; level terrace; drainage, natural; corn, oats, wheat, and hay; some manure applied; red clover does not do very well; sorrel, the principal weed.

8-A.—Discard, 2.36%. Orchard back of barn; cleared 35 years; soil, red; subsoil, red; rolling highland; drainage, natural; clover has been grown; red clover does fairly well; sorrel, the principal weed.

9-A.—Discard, 2.38%. North of barn; cleared 50 years; soil, light yellow; subsoil, darker yellow; rolling highland; level area in rolling field; drainage, natural; rotation of oats, wheat and clover; manure applied every 3 or 4 years; some fertilizer applied for wheat; red clover grown; does fairly well.

10-A.—Discard, 8.41%. Across road from barn; cleared 20 years; soil, light yellow; subsoil, yellowish; level highland terrace; drainage, natural; rotation of corn, wheat, clover and timothy; manure applied occasionally; some fertilizer; some hydrated lime; red clover grown; red clover does fairly well; considerable sorrel.

11-A.—Discard, .78%. Near bridge southeast of farm; cleared 20 to 30 years; soil, reddish; subsoil, reddish; level terrace; drainage, natural; rotation of tomatoes, wheat and clover; mixed fertilizer applied; some lime; red clover grown; red clover does fairly well.

12-A.—Discard, .94%. Terrace back of orchard; cleared 50 years; soil, light gray; rolling terrace; drainage, natural; corn and hay grown; some clover grown; sorrel and poverty grass, the principal weeds.

13-A.—Discard, 15.8%. Across road from schoolhouse; cleared 50 years; soil, light gray; level terrace; drainage, nat-

ural and some artificial; land mostly in meadow, now in cowpeas; some fertilizer applied; cowpeas grown; corresponding land not tile drained shows very poor meadows full of sorrel, broomsedge, etc.

14-A.—Discard, 4.44%. Center of farm; oak, cherry and some poplar originally grew on land; cleared 100 to 125 years; rolling highland; drainage, natural; rotation 3 years; corn, oats, clover and potatoes; yield, oats 25 bushels, corn 60 bushels, clover 2 tons, potatoes 200 bushels; some manure applied each three years; 200 pounds acid phosphate on all except potatoes; 1600 pounds home mixed; no lime; clover grown; red clover does fairly well; joint grass and foxtail, the principal weeds.

15-A.—Discard, 3.65%. South of house along road; oak originally grew on land; cleared over 100 years; soil, light brown; subsoil, dark yellow mottled; nearly level terrace; drainage, natural; meadow, one crop of corn 15 years ago; about one ton per acre; timothy predominates; no red clover sown; moss, sedge, running briers, cinquefoil, and yarrow, the principal weeds.

16-A.—Discard, 1.55%. Experiment Station plots; soil, light yellow; level highland; drainage, natural and artificial; variety of crops grown; plot 21; no manure applied; no fertilizer; no lime; red clover does not do well; sorrel and yellow trefoil, the principal weeds.

17-A.—Discard, 20.39%. Pine knob; cleared 5 years; soil, light brown; subsoil, yellowish brown; rolling highland; drainage, natural; orchard; crimson clover grown; sorrel, the principal weed; land cleared and farmed years ago but allowed to run wild again.

18-A.—Discard, 2.05%. Orchard on hill back of house; cleared 25 to 30 years; soil, red; subsoil, red; drainage, natural, not very good; orchard sown in clover; no manure applied; no lime; red clover grown; red clover does well.

19-A.—Discard, 26.41%. Oak land; cleared 5 years; soil, dark gray; subsoil, light gray; rolling highland; orchard; crimson clover grown; sorrel, the principal weed; cleared from forest years before but covered with second growth and this cleared off about 5 years; drainage, natural.

20-A.—Discard, 80.34%. Recently cleared orchard land.

21-A.—Discard, 2.57%. Northeast of barn, second field; cleared many years; soil, light gray; subsoil, yellowish; roll-

ing highland or second terrace; drainage, natural; rotation of corn, wheat, hay and tobacco; very little manure applied; very little fertilizer; no lime; red clover very poor; sorrel, the principal weed; very poor growth of grass.

22-A.—Discard, .84%. South of Elmwood church; cleared 50 years; soil, grayish; subsoil, grayish; level terrace; drainage, natural; rotation of corn, wheat, clover and tobacco; some manure applied; red clover grown; red clover does fairly well.

23-A.—Discard, 1.40%. Cleared many years; no rotation practiced; yield of crops not known; last potatoes no good; do not know what grasses predominate; no fertilizer applied; no lime; some white clover grown; red clover does not do well; milkweed, the principal weed.

24-A.—Discard, 41.74%. Cleared over 50 years; Apple Pie Ridge; soil, yellow; subsoil, yellow; rolling highland; drainage natural; nothing but orchard; 3-year average, 79 barrels apples; 400 pounds yearly of 4-10-8 fertilizer; no lime; no legumes; red clover would do well if given a chance; cheat grass, the principal weed; a very profitable orchard.

25-A.—Discard, 32.28%. On top of ridge; cleared over 50 years; rolling highland; drainage, natural; nothing but orchard cultivation; 3-year average, 79 barrels apples per acre; 400 pounds yearly of 4-10-8 fertilizer; no legumes grown; never tried red clover; cheat grass the principal weed; a good yielder of apples.

26-A.—Discard, 33.33%. Center of farm; cleared over 50 years; soil, red; subsoil, red; rolling highland; drainage, natural; cover crops in fall; peaches good, apples only fair, about 40 barrels per acre; 4-10-7 fertilizer and lime applied occasionally; crimson clover and cowpeas grown; never tried red clover; good soil for peaches if nitrogen is added; a little light for apples.

27-A.—Discard, 46.78%. Cleared only 10 years; soil, yellow; subsoil, yellow; level; drainage, natural; cowpeas and soybeans grown; orchard; not bearing; 400 pounds 4-8-7 fertilizer applied now and then; yellow shale soil, naturally poor; trees show neglect soon; manures and clovers help considerably.

28-A.—Discard, 21.98%. Soil, brown; subsoil, brown; Apple Pie Ridge; rolling highland; drainage, natural; 3-year average, 79 barrels per acre; 400 pounds 4-8-7 fertilizer

yearly; cover crops 10 year ago; cheat grass, the principal weed; heavy growth of cheat grass plowed under each year.

29-A.—Discard, 11.06%. Cleared 75 years; soil, yellowish brown; subsoil, yellow to brown; rolling highland; drainage, natural; corn grown only when orchard is young; orchard not bearing; 300 pounds 4-10-8 fertilizer applied occasionally; some clover grown; orchard about 10 years; not taking inter-crops off any more; good soil; outcrops of limestone.

30-A.—Discard, 52.30%. Cleared 50 years; soil, yellow; subsoil, yellow; rolling highland; drainage, natural; rotation of corn, oats and wheat; low yield; very little manure applied; 200 pounds 0-8-3 fertilizer applied occasionally; ground poor, trees doing poorly.

31-A.—Discard, 20.31%. Soil, yellow; subsoil, yellow; level overflow; drainage, natural; good apple yield, 60 barrels per acre; light applications of manure; just out of soapstone area; raising good crops.

32-A.—Discard, 17.39%. Cleared 50 years; soil, brown to black; subsoil, brown; level; no rotation practiced; 68 barrels apples per acre; 400 pounds 2-10-8 fertilizer yearly; crimson clover grown; red clover does well; good soil; high-producing orchards; clovers always plowed under.

33-A.—Discard, 40.23%. Cleared 50 years; soil, yellowish brown; subsoil, yellow; drainage, natural; good yield; manure occasionally applied about weak trees; 300 to 400 pounds 4-10-8 fertilizer when cropped; crimson clover grown; red clover does well; a good orchard on Apple Pie Ridge, well taken care of.

34-A.—Discard, 59.04%. Pine originally grew on land; cleared 40 years or more; soil, blue to gray; subsoil, bluish gray; (black slate); drainage, natural; yield low, about 30 barrels apples; occasionally 200 pounds 4-8-10 fertilizer applied; red clover does well; poor soil; manures and clovers help wonderfully.

35-A.—Discard, 16.08%. Pine originally grew on land; cleared 30 years or more; soil, yellow to bluish; subsoil, yellow and black slate; rolling terrace; drainage, natural; yield not very high; fertilizer applied occasionally; crimson clover grown; red clover does well.

36-A.—Discard, 41.12%. Cleared 40 years or more; soil, yellow to brown; subsoil, yellow; Apple Pie Ridge; rolling highland; yield high, 70 barrels; manure occasionally about trees; 4-10-8 fertilizer when crop is present; crimson clover grown; red clover does well; good soil; a good orchard well taken care of.

37-A.—Discard, 7.07%. Cleared 40 years; soil, yellowish brown; subsoil, yellow; level; drainage, natural; clean cultivation now; not bearing; manure and 4-10-8 fertilizer occasionally applied; some crimson clover grown; red clover does well.

38-A.—Discard, 11.19%. Cleared 40 years at least; soil, brown; subsoil, brown to yellow; rolling terrace; drainage, natural; yield good, 70 barrels average; manure applied occasionally; 500 pounds 4-10-8 fertilizer applied yearly; burned lime applied 1-10 years; crimson clover grown; red clover does well; good orchard; good management; cheat grass; outcrop of limestone.

39-A.—Discard, 1.32%. South of house; oak land; cleared 80 years; soil, chocolate; subsoil, yellowish; rolling highland; drainage, natural; yield rather low but getting better; no manure applied; fertilized heavily last few years; no lime; red clover grown; sorrel, the principal weed; probably in tobacco for years but for last 20 years corn, buckwheat, timothy and clover.

40-A.—Sugar and black walnut originally grew on land; cleared 65 to 70 years; soil, black; subsoil, gray; level, first bottom; drainage, natural; rotation of corn, oats, clover and timothy; no manure applied; no fertilizer; no lime; clover grown; red clover does well; present ownership 18 years; previous to this land had been poorly farmed.

41-A.—Discard. A typical black sand.

42-A.—West of road; cleared a great many years; soil, dark red; subsoil, red; rolling highland; rotation of corn, wheat and hay; little manure applied; no fertilizer; no lime; clover grown; soil covered with fragments of limestone; at present land is in alfalfa.

43-A.—Southwest of barn; oak, sugar, beech and poplar originally grew on land; cleared 75 or 80 years; soil, chocolate; level terrace; needs drainage; rotation of corn, wheat and timothy; 40 or 50 bushels corn; several applications of ma-

nure; no fertilizer; no lime; once in cowpeas, once in beans; clover formerly did well, though not now; pea vines, the principal weeds.

44-A.—South of house; oak and maple originally grew on land; cleared 40 to 50 years; soil, dark gray; subsoil, mottled; level bottom swamp; mostly grass, corn years ago; no manure applied; no fertilizer; no lime; typical "Meadows" from Little Clear Creek.

45-A.—Practically same as 44-A from wet undrained bottom meadow land.

46-A.—West of barn; oak and chestnut originally grew on land; cleared 75 years; soil, chocolate; subsoil, dark brown; level highland; rotation of corn, oats, wheat and hay; manure applied occasionally; acid phosphate 10-12 years; no lime; red clover grown; typical soapstone land.

47-A.—South of barn; oak, poplar and walnut originally grew on land; cleared 75 years; soil, dark gray; subsoil, light gray; mostly pasture for some time; some manure applied; no fertilizer; no lime; red clover grown. This should be typical limestone soil.

48-A.—Lower end of Buffington Island. This sample was taken from side of exposed strata along river shore where river had cut away into the bank.

49-A.—Cottonwood and sycamore originally grew on land; cleared 75 years or more; soil, black; subsoil, dark brown; level overflow; drainage, natural; all corn, occasionally watermelons; 60 to 65 bushels per acre; no manure applied; no fertilizer; no lime; no legumes grown; red clover does well; smartweed and pigweed, the principal weeds; very good corn land; potatoes do not do particularly well. This soil is from lower bottom, overflowing every year.

50-A.—Cottonwood and sycamore originally grew on land; cleared 75 years or more; soil, dark brown; subsoil, dark brown; level overflow; drainage, natural; all corn; 60 to 65 bushels per acre; no manure applied; no fertilizer; no lime; no legumes grown; red clover does well; smartweed and horseweed, the principal weeds; very good corn land; potatoes do not do very well; soil from upper bottom, overflowing every few years.

51-A.—Oak, pine and hickory originally grew on land; cleared 50 years; soil, reddish; subsoil, red; level terrace:

drainage, natural; rotation of corn, wheat, clover and timothy; 50 bushels corn, 12 bushels wheat; no manure applied; no fertilizer; no lime; clover grown; red clover does well; foxtail, ragweed, etc., the principal weeds; common type of small stream bottom soil in West Virginia, with Upshur highlands surrounding it.

52-A.—Oak, pine and hickory originally grew on land; cleared 5 years; soil, dark gray; subsoil, yellowish; steep highland; drainage, natural; pasture land; never in crops; bluegrass predominates; no manure applied; no fertilizer; no lime; no legumes grown; do not know if red clover does well; ragweed, sumac bushes, the principal growth; as near "virgin" soil as any in locality; example of soil which is cleared and no crops have since been removed; has been pastured very lightly.

53-A.—Creek bottom; oak, cottonwood and sycamore originally grew on land; cleared 50 years; soil, reddish brown; subsoil, red; level overflow and terrace; drainage, natural; corn and grass; no system until recently; 35 bushels corn; 2 tons hay; no manure applied; no fertilizer; no lime; clover grown; red clover does well; crab grass, ragweed and morning glory, the principal weeds.

54-A.—South side creek bottom; sycamore, cottonwood and oak originally grew on land; cleared 50 years; soil, reddish brown; subsoil, red; level overflow and terrace; drainage, natural; corn and grass; no system until recently; 35 bushels corn, 2 tons hay; no manure applied; no fertilizer; no lime; red clover grown; red clover does well; ragweed, crab grass and morning glory, the principal weeds.

55-A.—Center of farm; oak, hickory, tulip and pine originally grew on land; cleared 100 years; soil, light gray; subsoil, yellow; level terrace; drainage, natural; rotation of corn, timothy and cowpeas; 50 bushels corn; Japan clover, broomsedge and foxtail predominate; manure applied three times in last 6 years, thin 8 tons; 14% acid phosphate, 350 per acre; no lime; to be applied soon; cowpeas, crimson clover and red clover grown; red clover does not do well; foxtail, ragweed, sorrel and broomsedge, the principal weeds. This soil was very much depleted during slavery times; is oldest farm in country; was very much run down until about eight years ago; present owner has applied much fertilizer, at first bone meal, now acid phosphate.

56-A.—Oak, hickory, locust and tulip originally grew on land; cleared 75 years ago but has been in pasture and thicket

for 30 years; soil, gray; subsoil, reddish yellow; rolling highland; drainage, natural; pasture land; wild grasses, Canadian bluegrass and some Kentucky bluegrass; no manure applied; no fertilizer; no lime; do not know if red clover does well; sorrel, broomsedge and blackberries, principal growth; is to be cleared for peach orchard this year; was in locust and persimmon thicket until 2 years ago.

57-A.—Oak, hickory, poplar and ash originally grew on land; cleared 25 years; soil, light gray; subsoil, yellow; level terrace; drainage, natural; rotation of corn, wheat, clover and timothy; 35 bushels corn, 12 bushels wheat, 1 ton hay; poverty grass, foxtail and red top predominate; manure applied occasionally in spots; 16% acid phosphate, 400 pounds per acre every 4 years, and 2-8-2 before 1906; no lime; clover grown; red clover does only fairly well; foxtail and ragweed, the principal weeds.

58-A.—Oak and poplar originally grew on land; cleared 10 to 15 years; soil, grayish; subsoil, yellow; rolling highland; drainage, natural; sod; no manure applied; no fertilizer; no lime, no legumes; red clover does well; cinquefoil, the principal weed.

59-A.—Southeast of barn; white oak originally grew on land; cleared 50 years; soil, dark red; subsoil, dark red; rolling highland; poor drainage, too tenaceous; farmed perhaps earlier but last 30 years allowed to run to grass and underbrush; grubs, sorrel, etc., predominate; little manure applied; little fertilizer; no lime; red clover does well; wild sweet potatoes; briers and milkweed, the principal weeds.

60-A.—White oak originally grew on land; cleared 50 to 60 years; soil, red; subsoil, red; rolling highland; pasture, corn and wheat; 15 bushels wheat, 60 bushels corn; no manure applied; fertilizer applied once; no lime; no legumes grown; red clover does well; some sorrel.

61-A.—Discard, 2.21%. Oak and poplar originally grew on land; cleared 100 years; soil, yellowish; subsoil, light yellow; rolling highland; drainage, natural; poverty grass, etc., predominate; no manure applied; no fertilizer; no lime; legumes grown very little. This soil was in tobacco for years, but of late years has been practically abandoned and let go to briers, etc.

62-A.—South of barn; sugar trees originally grew on land; cleared 75 years; soil, reddish; subsoil, reddish; level

overflow; drainage, artificial; rotation of corn and wheat for 50 years; 60 to 70 bushels of corn; no manure applied; no fertilizer; no lime; very little clover; red clover does well; excellent land; overflows once a year.

63-A.—South of locks; cleared 100 years; soil, dark gray; subsoil, grayish; level overflow; drainage, natural; corn and wheat for years; 60 to 100 bushels corn, 20 to 30 bushels wheat; manure applied once or twice; no fertilizer; a little lime; clover grown; red clover does well. This land was overflowed in 1913 and covered with sand, etc.

64-A.—Discard, 23.12%. White oak originally grew on land; cleared 35 years; soil, dark brown; subsoil, reddish; rolling highland; corn and wheat, mostly wheat; 12 to 15 bushels; bluegrass predominates; no manure applied; no fertilizer; no lime; cowpeas a few years; red clover does well. The limestone outcrop was in form of good sized slabs mixed with the soil.

65-A.—Discard, 2.12%. North of barn; oak and poplar originally grew on land; cleared 75 years; soil, grayish; subsoil, yellowish; rolling highland; drainage, natural; corn, oats and hay, also wheat; manure applied every few years; a little complete fertilizer applied; no lime; red clover sown; sapling clover does well; yarrow, cinquefoil, sorrel and some poverty grass, the principal weeds.

66-A.—Discard, 5.49%. One mile north of Masontown, 100 yards east of pike; oak, maple and chestnut originally grew on land; cleared 20 years; soil, light brown; subsoil, light yellow; rolling highland; drainage, natural; corn, wheat, grass; pasture mostly; 60 bushels corn, 1½ tons hay; now in potatoes; 3 cattle supported to the acre; manure applied twice, 4 tons per acre; acid phosphate, 16%, 500 pounds per acre; 2 tons lime per acre; clover grown; red clover does well; cinquefoil and briers, the principal weeds; now in fine cultivation; promises 150 bushels potatoes per acre; rather loose and friable; one of the typical potato soils.

67-A.—Discard, 5.79%. 150 yards northeast of barn; oak, walnut, and locust originally grew on land; cleared 50 years; soil, brown; subsoil, light yellow; rolling highland; drainage, natural; corn, oats, grass (mowed 3 times); pasture before; 50 bushels corn, 40 bushels oats; bluegrass and redtop predominate; 3 acres per steer; manure applied 3 times, 8 tons to the acre; 200 pounds 16% acid phosphate to the acre; limed

10 years ago, 125 bushels; good clover; red clover does well; yarrow and cinquefoil, the principal weeds; north end of hill typifies best pasture land in district.

68-A.—Discard, 2.16%. One-half mile west of house; water oak, ash, and hickory originally grew on land; cleared 40 years; soil, black to gray; subsoil, bluish gray; level overflow; no drainage; pasture; bluegrass, swamp; no manure applied, no fertilizer, no lime; iron weed, mint, alders, and some sorrel, the principal growths.

69-A.—Discard, 20.00%. Southeast of house; white oak originally grew on land; cleared 50 years; soil, dark brown; subsoil, light yellow; rolling highland; drainage, natural; rotation of corn, oats, wheat, and grass; 50 bushels corn; manure applied once in five years; acid phosphate and bone applied; lime applied two or three times, not for 8 or 9 years; some clover grown; red clover does well.

70-A.—Discard, 6.85%. Southeast of barn; oak, chestnut, poplar, and sugar originally grew on land; cleared 75 years; soil, light brown; subsoil, yellowish; rolling highland; rotation of corn, oats, buckwheat, and potatoes; 50 bushels corn; no manure applied for 5 years; some fair grade fertilizer and acid phosphate applied; limed every time plowed for 5 years; mostly timothy grown; red clover does fairly well; no sorrel, buck plantain.

71-A.—Discard, 15.00%. Southeast of barn; poplar and oak originally grew on land; cleared 75 years; soil, brownish red; subsoil, brick red; rolling highland; drainage, natural; rotation of corn, oats, timothy, and clover; 50 bushels corn; manured 3 times in 12 years; acid phosphate applied about 6 times in 12 years; limed 12 years ago, before that had several heavy applications; clover grown; red clover does well; rattle weed and deer tongue, the principal weeds. This farm has been farmed for 75 years and had been worn to the point 25 years ago where it was very unproductive.

72-A.—Discard, 3.11%. Northwest of barn; sugar maple and oak originally grew on land; part cleared 25 years, remainder 50 years; soil, dark brown; subsoil, yellowish; rolling highland; drainage, natural; potatoes, oats, and buckwheat grown; 150 bushels potatoes, 30 bushels buckwheat; several applications of manure; acid phosphate applied; several applications of lime; red clover grown; red clover does well. This is a typical potato and buckwheat soil.

73-A.—Discard, .51%. Bottom south of house; sugar trees originally grew on land; cleared 50 years; soil, red; subsoil, reddish; level overflow; no drainage; corn principally, some meadow; good corn land; no manure applied, no fertilizer, no lime; white clover grown; red clover does well.

74-A.—Discard, 1.80%. Northeast of barn; cleared 50 years; soil, grayish; subsoil, yellowish; rotation of corn, wheat, and timothy; a little manure applied, no fertilizer, no lime; some clover grown; red clover does not do very well.

75-A.—Discard, 3.93%. West of house; beech and sugar originally grew on land; cleared 50 or 60 years; soil, dark brown; subsoil, light brown; level terrace; rotation of tobacco, corn, and wheat; some manure applied, some fertilizer, no lime; red clover does well. This should be a typical sample of tobacco soil. Grows best quality Burley of reddish yellow color.

76-A.—Discard, 1.40%. South of barn; cleared 75 years; soil, gray; subsoil, yellowish; level terrace; rotation of corn, oats, wheat, and timothy; some manure applied, not much, no fertilizer, no lime; no legumes grown; red clover does not do well; poverty grass and mint, the principal weeds. This soil is very unproductive at present. It is covered with poverty grass although it has been sown to timothy.

77-A.—Discard, 1.38%. Soil, light gray; subsoil, bluish; level terrace; no drainage; no rotation; oats poor crop; no manure applied, no fertilizer, no lime; no legumes grown; red clover does not do well; land seriously in need of drainage; quite flat; this sample typical of large area of this kind of land.

78-A.—Discard, 1.76%. Soil, light red; subsoil, yellowish; corn and timothy grown.

79-A.—Discard, 1.69%. West of house; cleared 50 years; soil, brown; subsoil, light brown; level terrace; rotation of wheat, corn, and timothy, mostly wheat; not much manure applied, no fertilizer, one application 2000 pounds $CaCO_3$; no legumes grown lately; red clover does not do very well.

80-A.—Discard, .84%. East of barn; cleared 75 years; soil, dark gray; subsoil, light gray; level overflow; rotation of corn, wheat, and timothy; manure applied occasionally, fertilizer occasionally, one application of lime last year; clover grown; red clover does fairly well.

81-A.—Discard, 15.75%. North of barn; oak, hickory, beech, and walnut originally grew on land; cleared 10 years; soil, dark brown; subsoil, yellow; rolling highland; drainage, natural; rotation of corn, oats, and clover; 40 bushels corn, 50 bushels oats, 1½ tons clover; bluegrass predominates; no manure, no fertilizer, no lime; clover grown; red clover does fairly well; milkweed, briers, and whitetop, the principal weeds.

82-A.—Discard, 2.03%. North of house; cleared 50 years; soil, light red; subsoil, light red; rolling highland; rotation of corn, wheat, and timothy; yield not very high; no manure applied, no fertilizer, no lime; no legumes grown.

83-A.—Discard, 2.05%. North of barn; heavily manured; this sample is typical but has been heavily manured and is underlain with mussel shells evidently left by Indians.

84-A.—Dicard, 1.46%. Cleared probably 100 years; soil, light gray; subsoil, yellowish; level terrace; rotation of corn, wheat, and timothy; very little manure applied, no fertilizer, no lime; red clover does not do well; typical of soils in Teays Valley; soil covered with cinquefoil; very little grass.

85-A.—Discard, 1.21%. Hickory originally grew on land; cleared 100 years; soil, dark gray; subsoil, yellow and blue; artificial drainage; before draining, swampy; meadow up to 20 years ago; 3 tons hay; 80 bushels corn; 5 applications of 8 tons of manure, 2500 pounds acid phosphate; limed, 1 ton CaO per acre; clover and cowpeas, mostly clover; red clover does well; some sorrel. This sample represents the flat land.

86-A.—Discard, 4.16%. North of buildings; oak, walnut, and sycamore originally grew on land; cleared 50 years; soil, black; subsoil, olive; level overflow; artificial drainage needed; no rotation in old meadow; consists of yarrow, daisy, poverty grass, and is a typical "run down" meadow.

87-A.—Discard, 8.48%. South of barn; oak, chestnut, and some poplar originally grew on land; cleared 75 years; soil, light brown; subsoil, yellowish; rolling highland; drainage, natural; corn, wheat, largely grass; sorrel, briers, etc., predominate; no manure applied, no fertilizer, no lime; no legumes grown; red clover does not do well; rock close to surface.

88-A.—Discard, 1.88%. Poplar, beech, and sugar originally grew on land; cleared 50 years; soil, brown; subsoil, brown; level overflow; artificial drainage; mostly meadow,

some corn and some oats; 75 bushels corn; a little manure applied, a little fertilizer, a little lime; no legumes grown; limestone on tops of hills in small amounts.

89-A.—Discard, 2.77%. South of house; oak, hickory, and walnut originally grew on land; cleared 100 years; soil, dark brown; subsoil, chocolate; rolling highland; drainage, natural; rotation of corn, oats, and clover; 50 bushels corn, 40 bushels oats, 1 ton hay.

90-A.—Discard, 7.31%. East of barn; sugar trees originally grew on land; cleared 100 years; soil, dark brown; subsoil, yellowish; rolling highland; drainage, natural; pasture more than ½, farmed 12 or 15 years; 60 bushels corn, 2 tons soybean hay; only 1 application of manure, 4 or 5 applications 250 pounds phosphate; limed once, 1 ton CaO; 2 crops soybeans, 1 crimson clover; red clover does well; sorrel, the principal weed. This sample represents the hill land under cultivation.

91-A.—Discard, 9.88%. Northeast slope, oak originally grew on land; cleared 75 years; soil, light brown; subsoil, yellowish; rolling highland; drainage, natural; mostly grass and pasture; poverty grass predominates; no manure applied, no fertilizer, no lime; no legumes grown; red clover does not do well; sorrel, the principal weed; typical poverty grass, northeastern slope.

92-A.—Discard, 10.42%. Northwest slope; walnut and poplar originally grew on land; cleared 75 years; soil, dark brown; subsoil, yellowish; rolling highland; drainage, natural; bluegrass and poverty grass predominate; no manure applied, no fertilizer, no lime; no legumes grown. This is same soil as 91-A, that is, it is derived from the same rock but has northwestern exposure instead of northeastern.

93-A.—Discard, .76%. South of barn; pine land; cleared 100 years; soil, grayish; subsoil, yellowish; under cultivation, corn, wheat, and timothy; no manure applied, no fertilizer; 2000 pounds $CaCO_3$ applied; soybeans grown; red clover does well; sorrel, the principal weed; this sample from farm which has been farmed for 100 years and is just now being well farmed.

94-A.—Discard, 1.01%. Northeast of barn; soil, grayish; subsoil, light gray; level terrace; rotation of corn, wheat, and timothy; little manure applied, no fertilizer; no legumes grown.

95-A.—Discard, 2.20%. Near barn; cleared 100 years; soil, chocolate; subsoil, yellowish; level terrace; in grass for years, farmed to alfalfa and corn; excellent corn crop now; bluegrass predominates; some manure applied, some acid phosphate, two applications of lime for alfalfa; alfalfa and red clover grown; red clover does well; this has probably been influenced by limestone from adjacent hill in which there is thin ledge. This had been bluegrass pasture for years.

96-A.—Discard, 1.04%. Oak, sycamore, and sugar originally grew on land; cleared 85 years; soil, reddish; subsoil, chocolate; level overflow; drainage, natural; rotation of corn, oats, and grass; 70 bushels corn; very little manure applied, some fertilizer, 1 ton lime per acre. The soil has been filled in largely the last ten years by overflow.

97-A.—Discard, 1.96%. Top of hill back of barn; cleared 50 years; soil, whitish; rolling highland; drainage, natural; hay grown; timothy predominates; acid phosphate applied; sorrel, the principal weed; land practically bare when Mr. Hardman bought it; treated with acid phosphate and got good crop of timothy.

98-A.—Discard, 1.11%. Sugar and oak originally grew on land; cleared 100 years; soil, light brown; subsoil, yellowish; level terrace, corn and wheat for years, under cultivation ¾ of 100 years; 50 bushels corn; 4 or 5 applications of manure, 4 or 5 small applications of fertilizer, limed twice; clover grown; red clover does fairly well; considerable plantain.

99-A.—Discard, 5.71%. Next creek; oak and hickory originally grew on land; cleared 50 years; soil, chocolate; subsoil, yellow; rolling terrace; drainage, natural; no rotation practiced; poverty grass, briers and redtop predominate.

100-A.—Discard, 1.40%. West of barn; land originally swamp; soil, black; subsoil, black; level overflow; artificial drainage 35 years ago but re-drained the last few years; grass, corn now; no manure applied, no fertilizer, no lime; no legumes grown.

101-A.—Discard, 2.25%. Soil, black; subsoil, yellowish; soil good for corn but unsatisfactory for grass.

102-A.—Discard, 1.05%. West of house; cleared 100 years; soil, reddish; subsoil, reddish; level overflow; drainage, natural; rotation of corn, wheat, timothy, and some clover; manure applied occasionally, some fertilizer, no lime; clover

grown occasionally; red clover does fairly well; this represents a flat field which overflows yearly or nearly that often; nice bottom field.

103-A.—Discard, 1.21%. Southeast of barn; sugar trees originally grew on land; cleared 10 years or so; soil, dark gray to brown; subsoil, brown; level overflow; no drainage; grass and pasture; no manure applied, no fertilizer, no lime; no legumes; some limestone upstream.

104-A.—Discard, 12.56%. East of house; cleared 50 years or more; soil, brown; subsoil, yellowish; land in grass; 5 acres or more to a steer; poverty grass and such grasses predominate; no manure applied, no fertilizer, no lime; no legumes grown; red clover does not do well; has been in meadow and pasture and nothing ever done but mow hay and pasture.

105-A.—Discard, 1.50%. Southwest of barn; white oak originally grew on land; cleared 75 years; soil, gray; subsoil, yellowish; rolling highland; drainage, natural; rotation of corn, wheat, timothy, and oats; some manure applied, very little, no fertilizer, no lime; legumes grown very little; red clover does not do well; poverty grass and wire grass, the principal weeds; this is typical of rather white soil of Jackson County.

106-A.—Discard, 1.07%. East of barn; white oak originally grew on land; soil, light brown; subsoil, yellowish; rolling terrace; drainage, natural; soil in poor shape and has not been well farmed for years.

107-A.—Discard, 7.40%. Southeast of barn; oak and pine originally grew on land; cleared 75 years, second growth until 5 years ago; soil, grayish; subsoil, yellowish; rolling highland; corn, wheat, and timothy years ago; some fertilizer applied, no lime; Legumes do not grow well; red clover does not do well; sorrel, poverty grass, pennyroyal, and cinquefoil, the principal weeds; has been farmed for years and then allowed to grow up to underbrush.

108-A.—Discard, 1.20%. Northeast of house; oak originally grew on land; cleared 12 years; soil, gray; subsoil, yellowish; level highland; drainage, natural; orchard; no manure applied, no fertilizer, no lime; red clover does well; sorrel, the principal weed.

109-A.—Discard, 6.19%. North of church; oak and chestnut originally grew on land; cleared 75 to 100 years; soil,

grayish; subsoil, yellow; rolling highland; drainage, natural; rotation of corn, oats, wheat, and timothy; very little manure applied, a little fertilizer, no lime; no clover ever sown, do not know if red clover does well; cinquefoil, sorrel, and poverty grass, the principal weeds; this sample chosen from poorly farmed area now in meadow adjoining the church yard.

110-A.—Discard, 1.03%. Poplar originally grew on land; cleared 75 years; soil, chocolate; subsoil, chocolate; level terrace; drainage, natural; corn, wheat, and timothy, is now in watermelons; some manure applied, no fertilizer, no lime; legumes not grown to amount to anything; red clover does not do very well. This is excellent and typical watermelon soil.

111-A.—Discard, 2.45%. West of town; soil, yellowish brown; drainage, natural; covered with very poor wheat; probably never had any lime or fertilizer and very little manure.

112-A.—Discard, 2.31%. Poplar, sugar, and oak originally grew on land; cleared 100 years; soil, red; subsoil, red; rolling highland; drainage, artificial; alfalfa, cowpeas, clover several times; 3 tons alfalfa, 75 bushels corn; manured 7 or 8 times, 3000 pounds acid phosphate, 3 tons CaO last 10 years; red clover does well.

113-A.—Discard, 3.61%. West of barn; chestnut originally grew on land; cleared 75 or 100 years; soil, light brown or gray; subsoil, yellowish; rolling terrace; drainage, natural; briers and broomsedge, corn this year; one application of manure, two or three applications of fertilizer, no lime; no legumes grown.

114-A.—Discard, 13.51%. West of house; white oak originally grew on land; cleared 25 years; soil, light gray; subsoil, yellowish; level highland; rotation of corn, oats, and timothy; acre yield not very high; 2 or 3 applications of manure, 1 application of fertilizer, 1 ton CaO applied; some clover grown, now ready for alfalfa; red clover does not do very well. The surface was covered with fragments of sandstone.

115-A.—Drainage, artificial; rotation of corn, oats, wheat, clover, and timothy; for yield see Ohio circular 144; analysis, Ohio bulletin 261; 6 inches surface soil; phosphorus, 664; potassium, 33,110; nitrogen, 1778; humus, 18800; calcium, 4720; magnesium, 7778. This soil corresponds to soil on plots in five-year rotation which has never received any fertilizer or manure since the experiments were begun in 1893.

## INTERPRETATION OF ANALYSES.

Nitrogen, phosphorus, and potassium are three elements of plant food which may be present in available forms in such small amounts in the soil as to be limiting factors in crop production. The foregoing analyses show the total number of pounds of these elements present but not the number of pounds which are available. It is recognized that the amount of available plant food materials in the soil is determined by three things:

1. The total amount of these elements present in the soil.

2. The extent to which organic matter is incorporated with the soil.

3. The extent to which the soil can be kept supplied with carbonate of lime in order that the normal processes of decay may take place readily.

If two soils were equally supplied with organic matter and limestone, and one of these soils contained twice the amount of nitrogen, phosphorus or potassium as did the other, it seems reasonable to believe that the one containing twice the total amount of these elements would also be able to supply the crop being grown with twice the amount of these elements in available form.

In considering the subject of soil fertility from the long time point of view it seems desirable, therefore, to know the total amounts of nitrogen, phosphorus and potassium, the amount of organic matter and the amount of carbonate of lime present in the soil. Knowing these things, we can plan ahead more intelligently as to how to proceed toward a permanent system of soil building.

Table IV shows the average of all the analyses of West Virginia soils so far made. The amount of organic matter is calculated by multiplying the total carbon by 1.724 which would mean that organic matter was 58% carbon. The limestone requirement indicates the number of pounds of limestone necessary to destroy all the acid in the surface soil to plow depth. For most crops it is desirable to have the soil well supplied with limestone.

TABLE IV.—Pounds per 2,000,000 Lbs. of Surface Soil.

| | Highest | Lowest | Average of All Soils | Plot 21, Exp. Sta. Farm |
|---|---|---|---|---|
| Nitrogen | 6,485 | 1,035 | 2,915 | 1,830 |
| Phosphorus | 3,635 | 355 | 1,095 | 590 |
| Potassium | 143,000 | 1,200 | 30,610 | 24,200 |
| Organic matter | 302,800 | 26,200 | 57,800 | 36,500 |
| Limestone requirement | 6,800 | 0 | 2,170 | 2,800 |

A study of the analyses of these soils will show that many of them are seriously depleted of phosphorus, nitrogen, and organic matter. Over 90% of the soils of West Virginia show a need of lime. Most of the soils are fairly well supplied with potassium.

We prefer to wait until more analyses have been made before discussing these analyses in detail. However, Table IV also gives the analysis of one of the check plots on the Experiment Station farm at Morgantown, and this shows that the average West Virginia soil so far analyzed is better than that on the Experiment Station farm. But a careful study of the analyses will show that many of the soils of the state would probably respond to fertilizer treatment much the same as does the soil on the Experiment Station farm.*

*See "Experiments with Fertilizers," Bulletin 155, West Virginia Agricultural Experiment Station.

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